EXHIBIT 7

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Al-Ali et al.

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(54) **MULTIPLE WAVELENGTH SENSOR SUBSTRATE**

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(58) **Field of Classification Search** 600/310, 600/331, 333, 336

See application file for complete search history.

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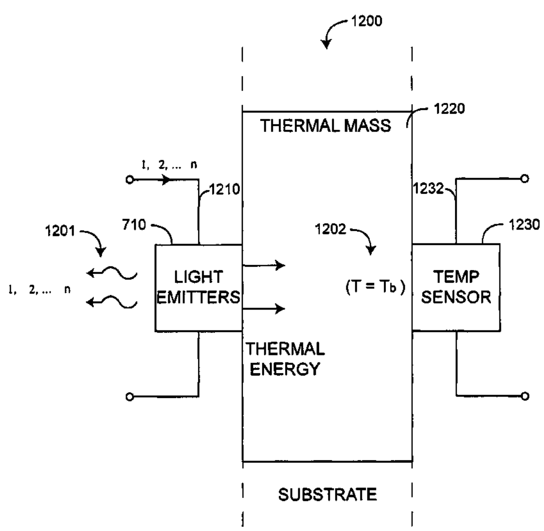
(57) **ABSTRACT**

A physiological sensor has emitters configured to transmit optical radiation having multiple wavelengths in response to corresponding drive currents. A thermal mass is disposed proximate the emitters so as to stabilize a bulk temperature for the emitters. A temperature sensor is thermally coupled to the thermal mass. The temperature sensor provides a temperature sensor output responsive to the bulk temperature so that the wavelengths are determinable as a function of the drive currents and the bulk temperature.

30 Claims, 48 Drawing Sheets



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6,836,679	B2	12/2004	Baker, Jr. et al.
6,839,579	B1	1/2005	Chin
6,839,580	B2	1/2005	Zonios et al.
6,839,582	B2	1/2005	Heckel
6,842,702	B2	1/2005	Haaland et al.
6,845,256	B2	1/2005	Chin et al.
6,847,835	B1	1/2005	Yamanishi
6,850,787	B2	2/2005	Weber et al.
6,850,788	B2	2/2005	Al-Ali
6,852,083	B2	2/2005	Caro et al.
6,861,639	B2	3/2005	Al-Ali
6,869,402	B2	3/2005	Arnold
6,882,874	B2	4/2005	Huiku
6,898,452	B2	5/2005	Al-Ali et al.
6,912,049	B2	6/2005	Pawluczyk et al.
6,917,422	B2	7/2005	Samsoondar et al.
6,919,566	B1	7/2005	Cadell
6,920,345	B2	7/2005	Al-Ali et al.
6,921,367	B2	7/2005	Mills
6,922,645	B2	7/2005	Haaland et al.
6,928,311	B1	8/2005	Pawluczyk et al.
6,931,268	B1	8/2005	Kiani-Azarbayjany et al.
6,931,269	B2	8/2005	Terry
6,934,570	B2	8/2005	Kiani et al.
6,939,305	B2	9/2005	Flaherty et al.
6,943,348	B1	9/2005	Coffin, IV
6,944,487	B2	9/2005	Maynard et al.
6,950,687	B2	9/2005	Al-Ali
6,961,598	B2	11/2005	Diab
6,970,792	B1	11/2005	Diab
6,975,891	B2	12/2005	Pawluczyk
6,979,812	B2	12/2005	Al-Ali
6,985,764	B2	1/2006	Mason et al.
6,987,994	B1	1/2006	Mortz
6,993,371	B2	1/2006	Kiani et al.
6,996,427	B2	2/2006	Ali et al.
6,999,904	B2	2/2006	Weber et al.
7,001,337	B2	2/2006	Dekker
7,003,338	B2	2/2006	Weber et al.
7,003,339	B2	2/2006	Diab et al.
7,006,856	B2	2/2006	Baker, Jr. et al.
7,015,451	B2	3/2006	Dalke et al.
7,024,233	B2	4/2006	Ali et al.
7,027,849	B2	4/2006	Al-Ali
7,030,749	B2	4/2006	Al-Ali
7,039,449	B2	5/2006	Al-Ali
7,041,060	B2	5/2006	Flaherty et al.
7,044,918	B2	5/2006	Diab
2001/0044700	A1	11/2001	Kobayashi et al.
2001/0045532	A1	11/2001	Schulz et al.
2002/0021269	A1	2/2002	Rast
2002/0038078	A1	3/2002	Ito
2002/0038081	A1	3/2002	Fein et al.
2002/0059047	A1	5/2002	Haaland
2002/0111748	A1	8/2002	Kobayashi et al.
2002/0154665	A1*	10/2002	Funabashi et al. 372/45
2002/0156353	A1	10/2002	Larson
2002/0161291	A1	10/2002	Kiani et al.
2002/0183819	A1	12/2002	Struble
2003/0109775	A1	6/2003	O'Neil et al.
2003/0120160	A1	6/2003	Yarita
2003/0139657	A1	7/2003	Solenberger
2003/0195402	A1	10/2003	Fein et al.
2004/0006261	A1	1/2004	Swedlow et al.
2004/0033618	A1	2/2004	Haass et al.

2004/0034898	A1	2/2004	Bruegl
2004/0059209	A1	3/2004	Al Ali et al.
2004/0064259	A1	4/2004	Haaland et al.
2004/0081621	A1	4/2004	Arndt et al.
2004/0092805	A1	5/2004	Yarita
2004/0133087	A1	7/2004	Ali et al.
2004/0138538	A1	7/2004	Stetson
2004/0138540	A1	7/2004	Baker, Jr. et al.
2004/0147823	A1	7/2004	Kiani et al.
2004/0158134	A1	8/2004	Diab et al.
2004/0158135	A1	8/2004	Baker, Jr. et al.
2004/0162472	A1	8/2004	Berson et al.
2004/0167382	A1	8/2004	Gardner et al.
2004/0176670	A1	9/2004	Takamura et al.
2004/0181134	A1	9/2004	Baker, Jr. et al.
2004/0199063	A1	10/2004	O'Neil et al.
2004/0204639	A1	10/2004	Casciani et al.
2004/0204868	A1	10/2004	Maynard et al.
2004/0262046	A1	12/2004	Simon et al.
2004/0267103	A1	12/2004	Li et al.
2004/0267140	A1	12/2004	Ito et al.
2005/0011488	A1	2/2005	Al Ali et al.
2005/0043902	A1	2/2005	Haaland et al.
2005/0049469	A1	3/2005	Aoyagi et al.
2005/0070773	A1	3/2005	Chin et al.
2005/0070775	A1	3/2005	Chin et al.
2005/0075546	A1	4/2005	Samsoondar et al.
2005/0085735	A1	4/2005	Baker, Jr. et al.
2005/0124871	A1	6/2005	Baker, Jr. et al.
2005/0143634	A1	6/2005	Baker, Jr. et al.
2005/0143943	A1	6/2005	Brown
2005/0148834	A1	7/2005	Hull et al.
2005/0184895	A1	8/2005	Petersen et al.
2005/0187447	A1	8/2005	Chew et al.
2005/0187448	A1	8/2005	Petersen et al.
2005/0187449	A1	8/2005	Chew et al.
2005/0187450	A1	8/2005	Chew et al.
2005/0187452	A1	8/2005	Petersen et al.
2005/0187453	A1	8/2005	Petersen et al.
2005/0197549	A1	9/2005	Baker, Jr.
2005/0197579	A1	9/2005	Baker, Jr.
2005/0197793	A1	9/2005	Baker, Jr.
2005/0203357	A1	9/2005	Debreczeny et al.
2005/0228253	A1	10/2005	Debreczeny
2005/0250997	A1	11/2005	Takeda et al.
2006/0030764	A1	2/2006	Porges et al.

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WO	WO 03/068060	8/2003

* cited by examiner

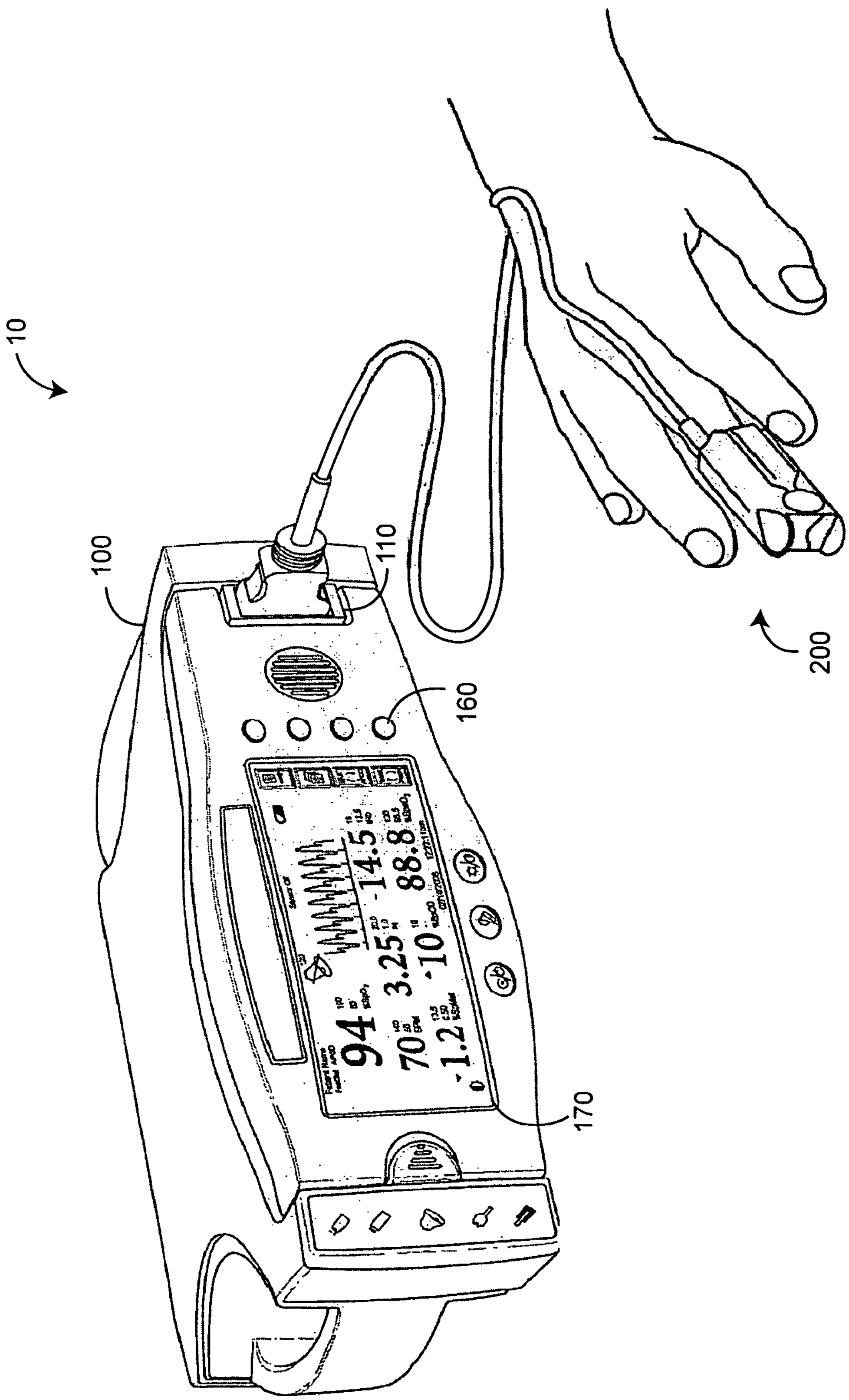


FIG. 1

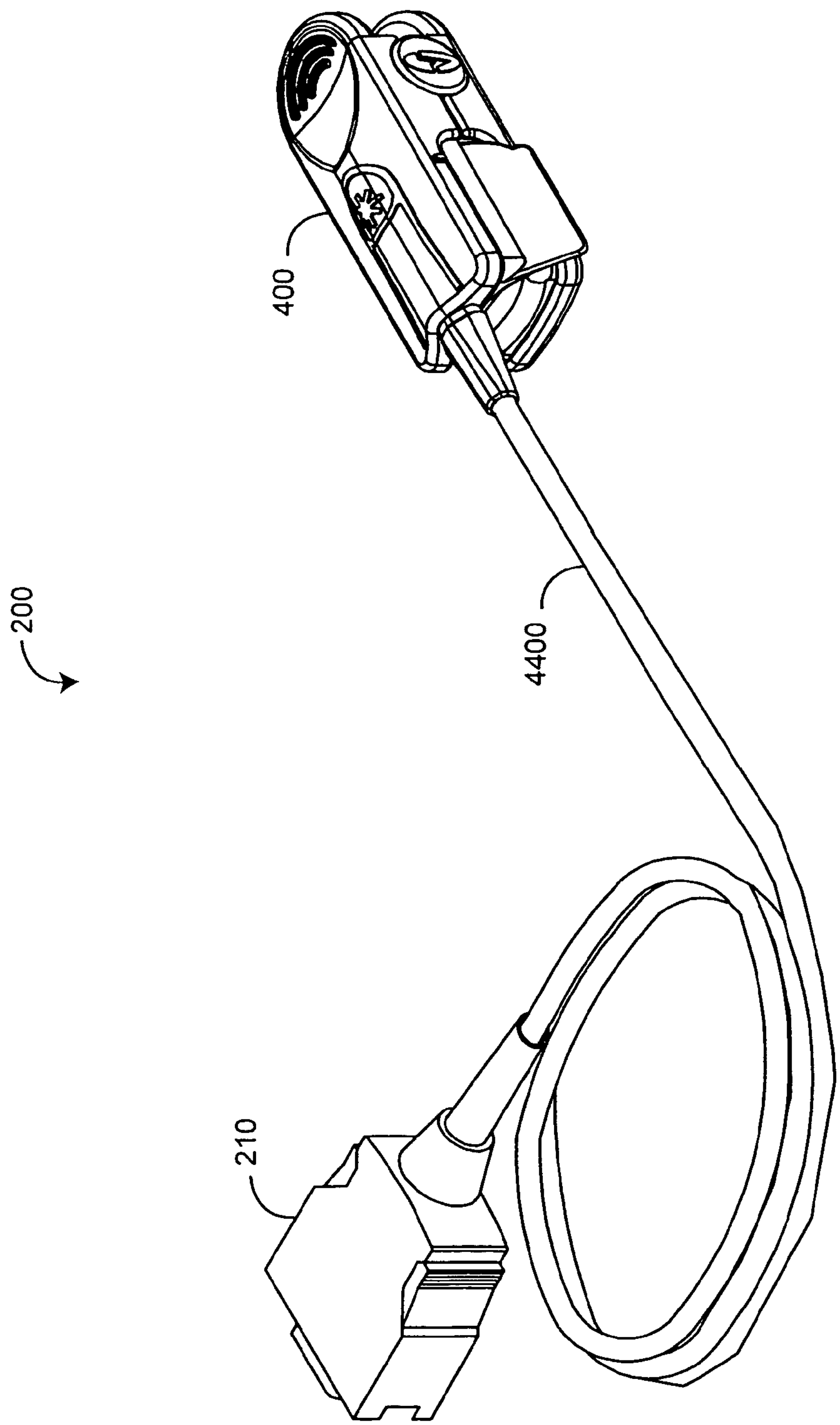


FIG. 2A

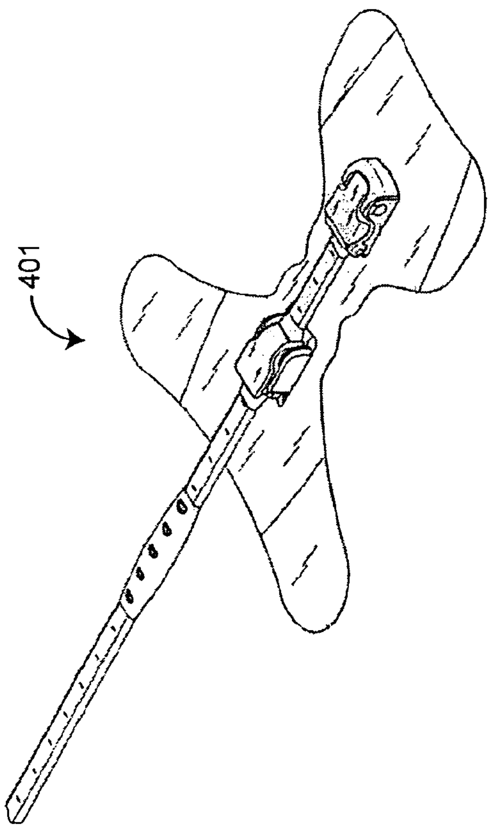


FIG. 2B

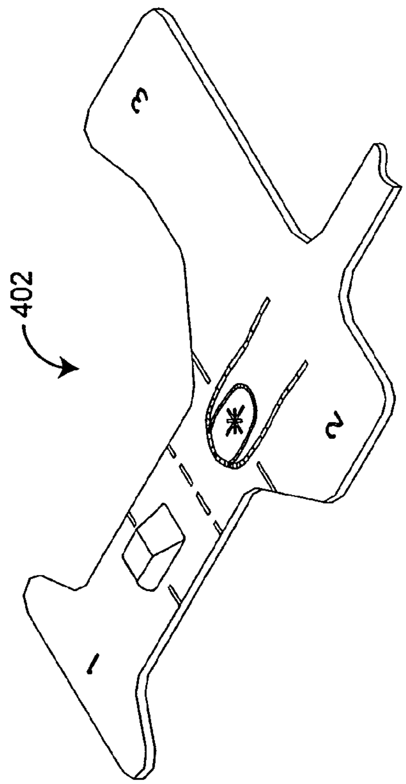


FIG. 2C

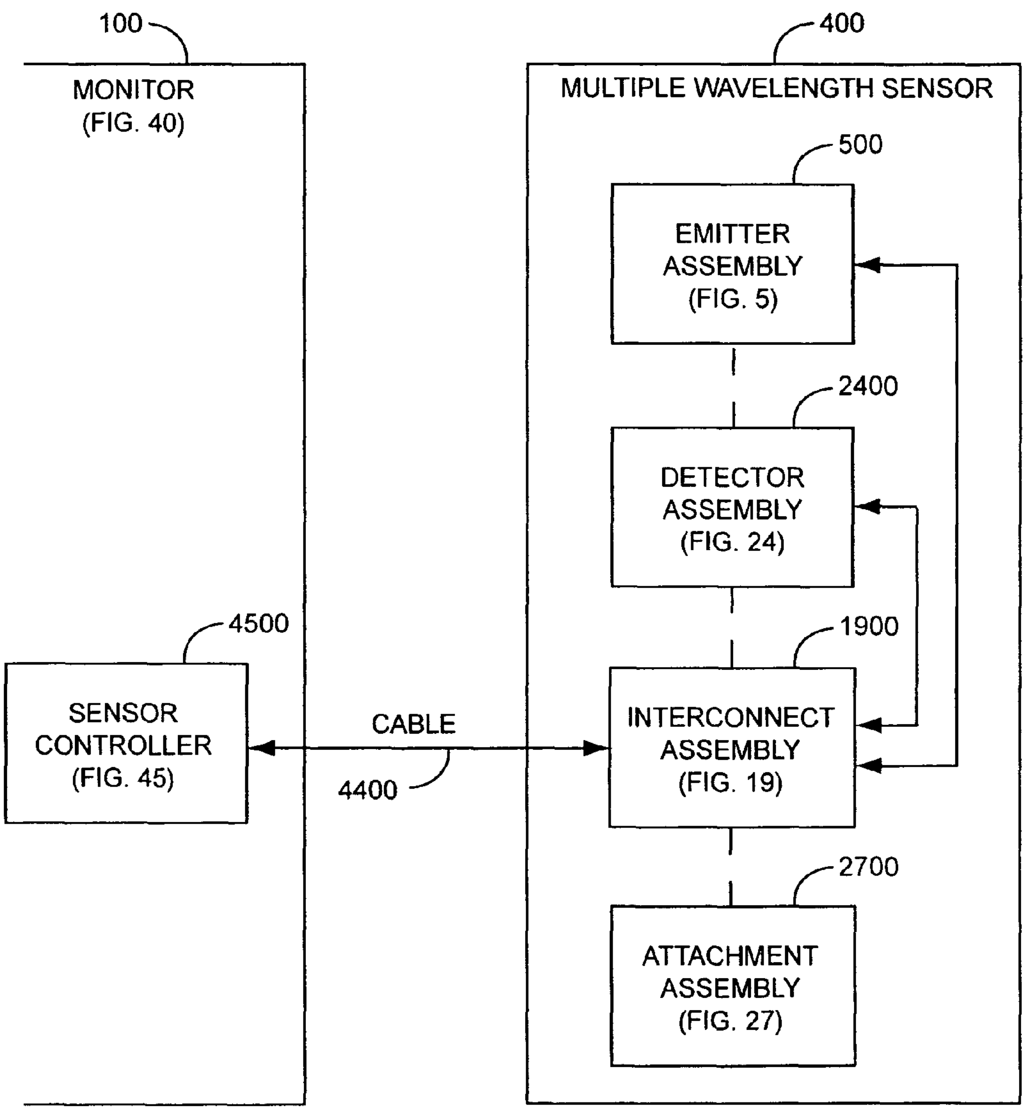

100
MONITOR
(FIG. 40)
4500
SENSOR
CONTROLLER
(FIG. 45)
CABLE
4400
400
MULTIPLE WAVELENGTH SENSOR
500
EMITTER
ASSEMBLY
(FIG. 5)
2400
DETECTOR
ASSEMBLY
(FIG. 24)
1900
INTERCONNECT
ASSEMBLY
(FIG. 19)
2700
ATTACHMENT
ASSEMBLY
(FIG. 27)

FIG. 3

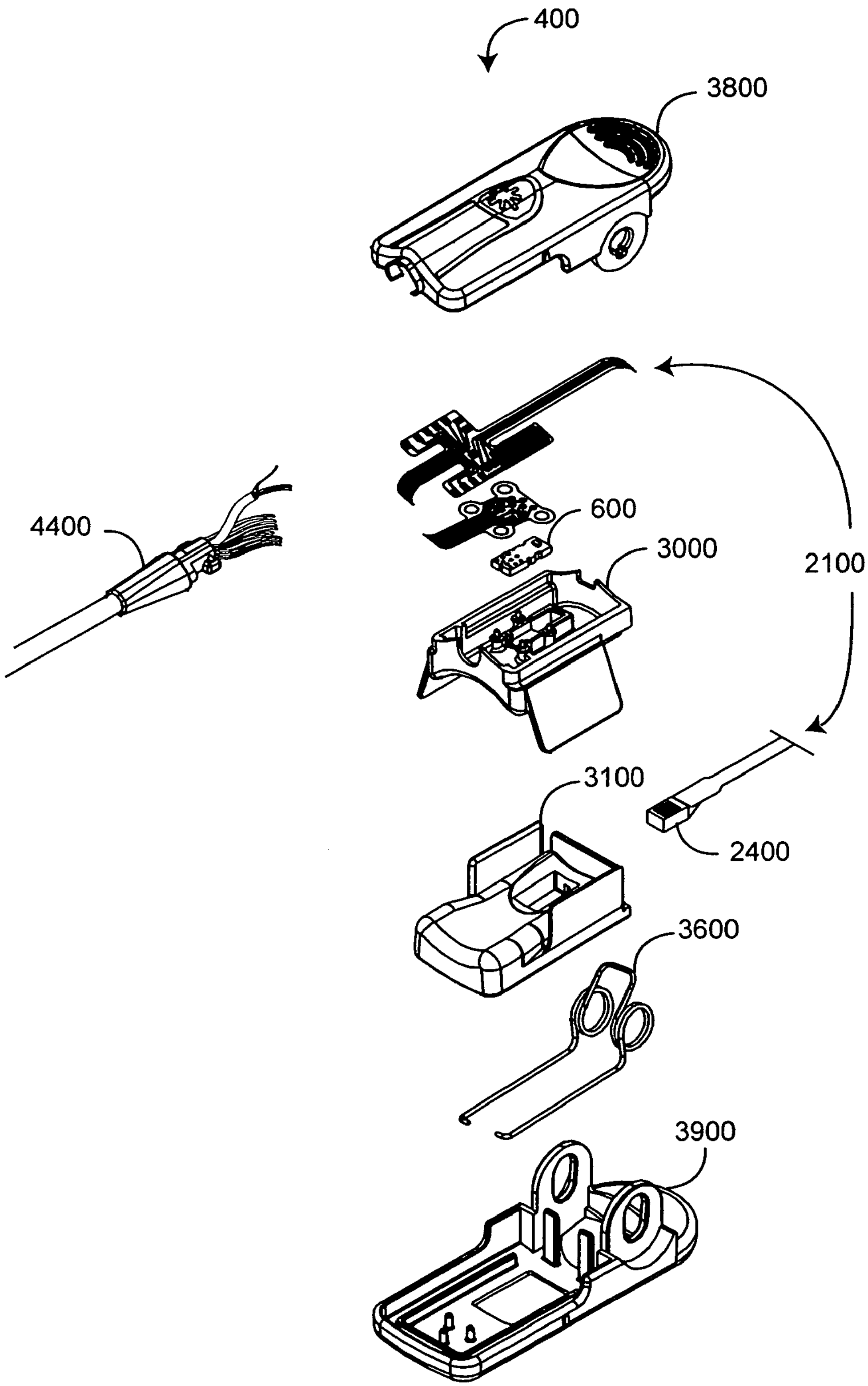


FIG. 4

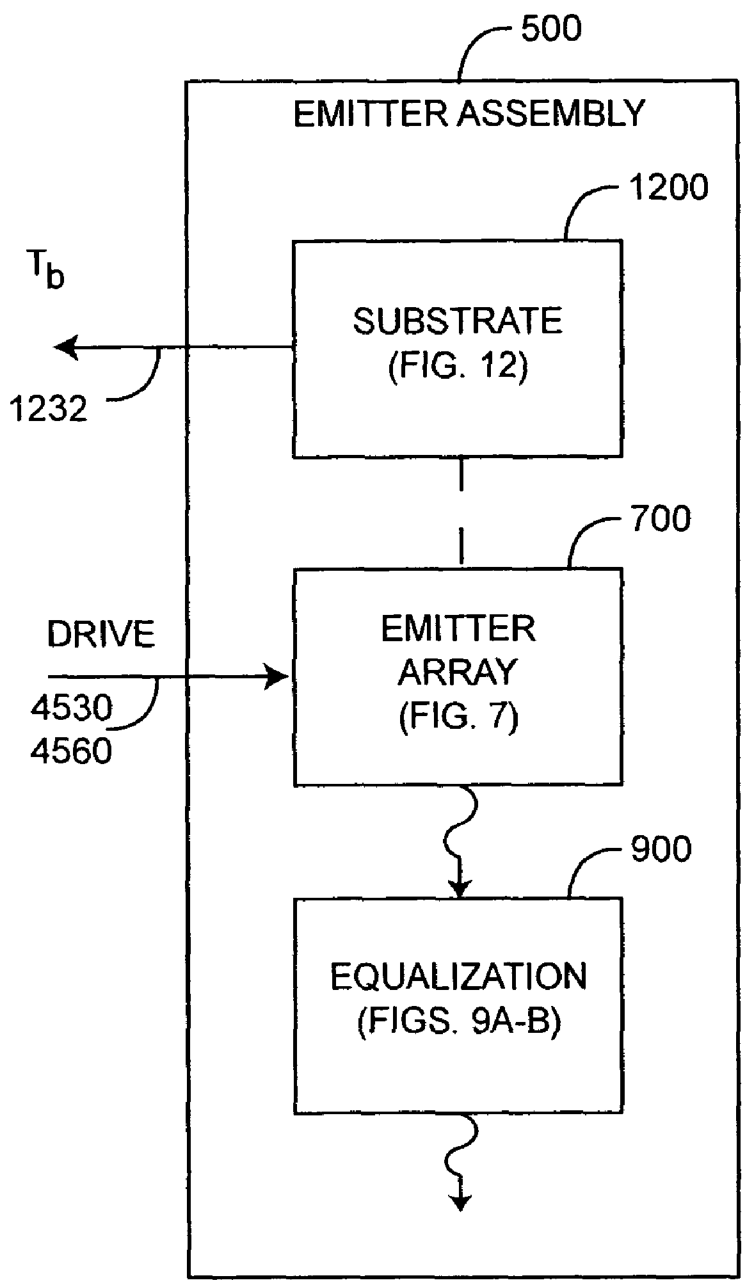

500
EMITTER ASSEMBLY
1200
T_b
SUBSTRATE
(FIG. 12)
1232
700
DRIVE
EMITTER
ARRAY
(FIG. 7)
4530
4560
900
EQUALIZATION
(FIGS. 9A-B)

FIG. 5

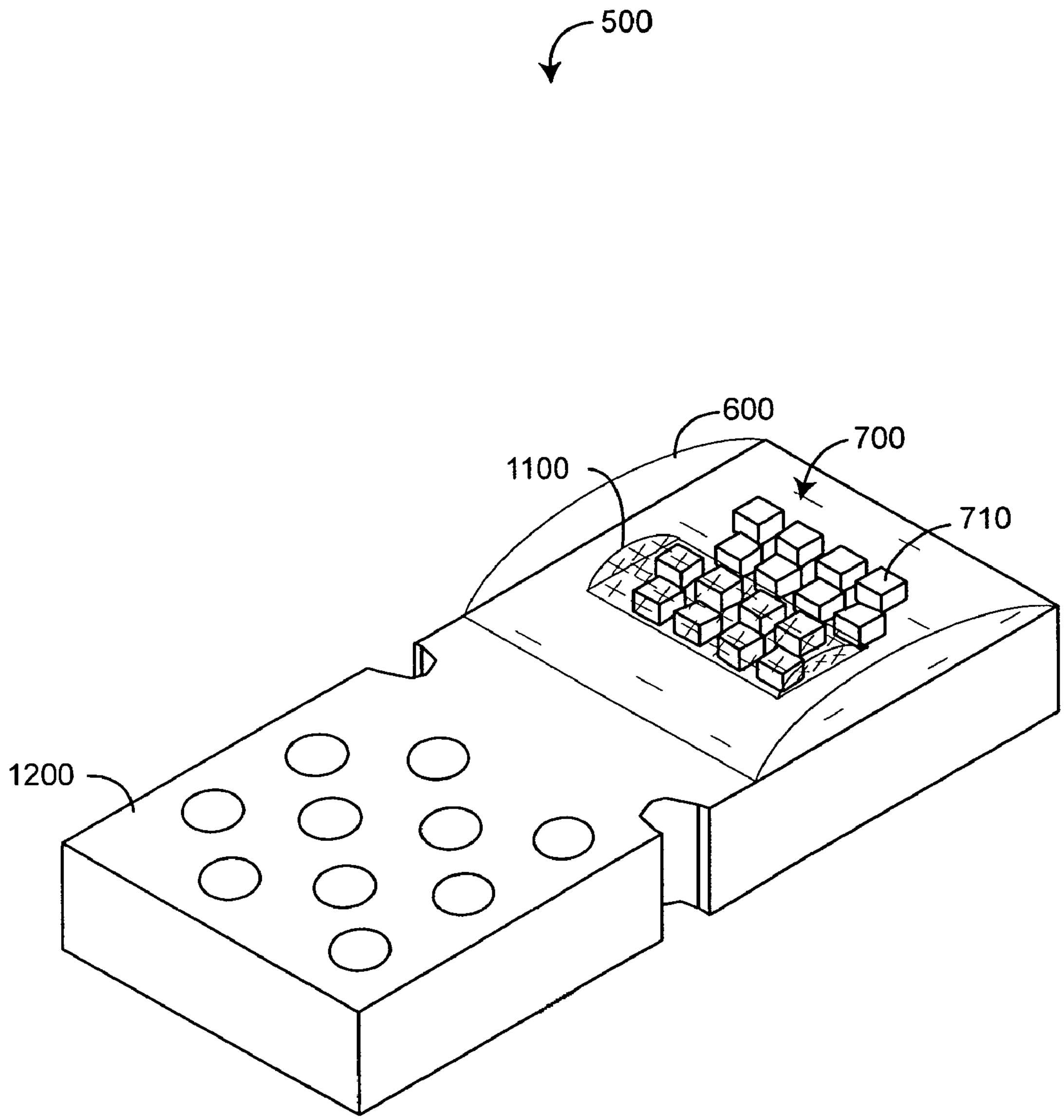
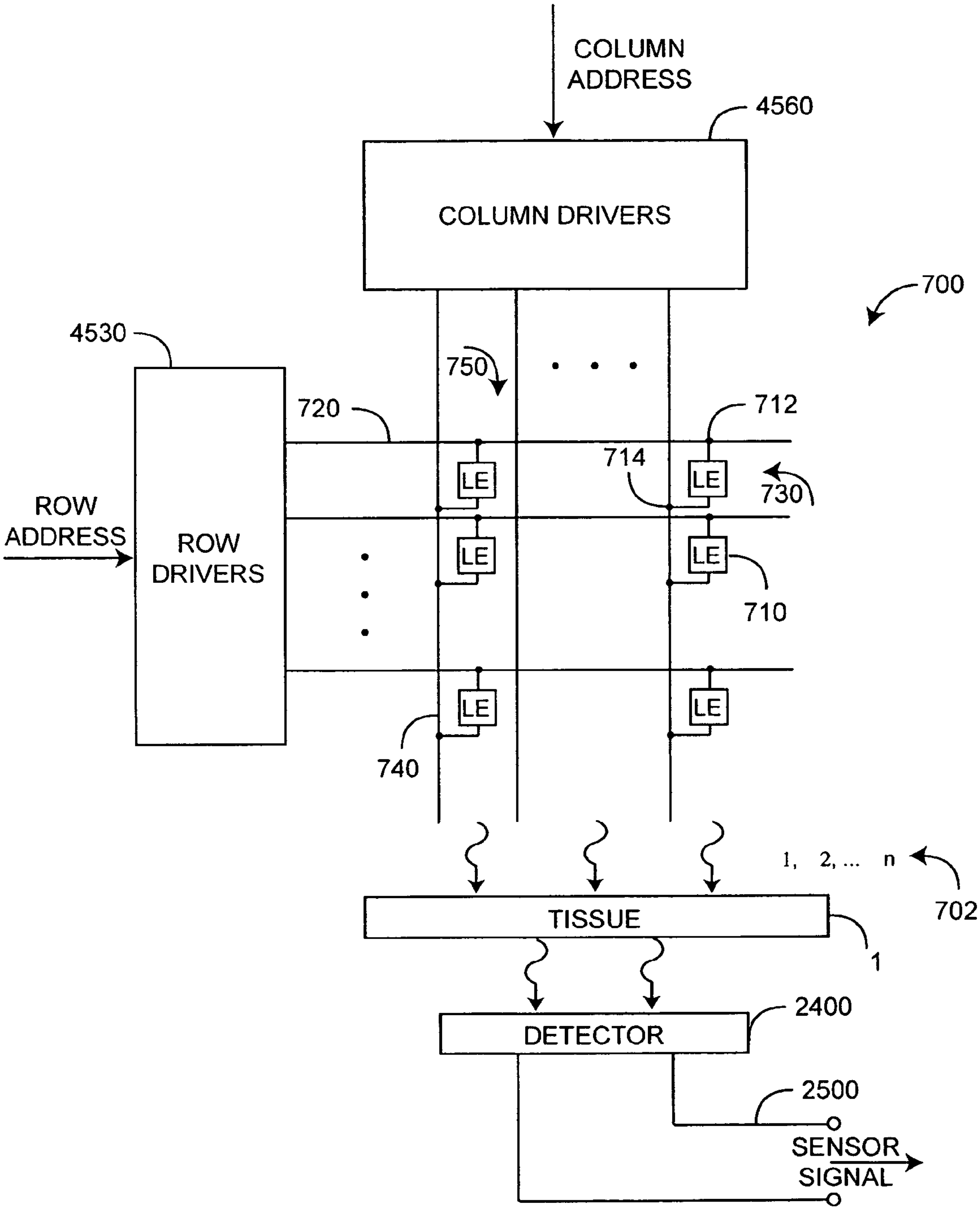


FIG. 6



COLUMN ADDRESS
4560
COLUMN DRIVERS
700
4530
750
720
712
714
730
ROW ADDRESS
ROW DRIVERS
LE
LE
LE
LE
LE
LE
710
740
1, 2, ... n
702
TISSUE
1
DETECTOR
2400
2500
SENSOR SIGNAL

FIG. 7

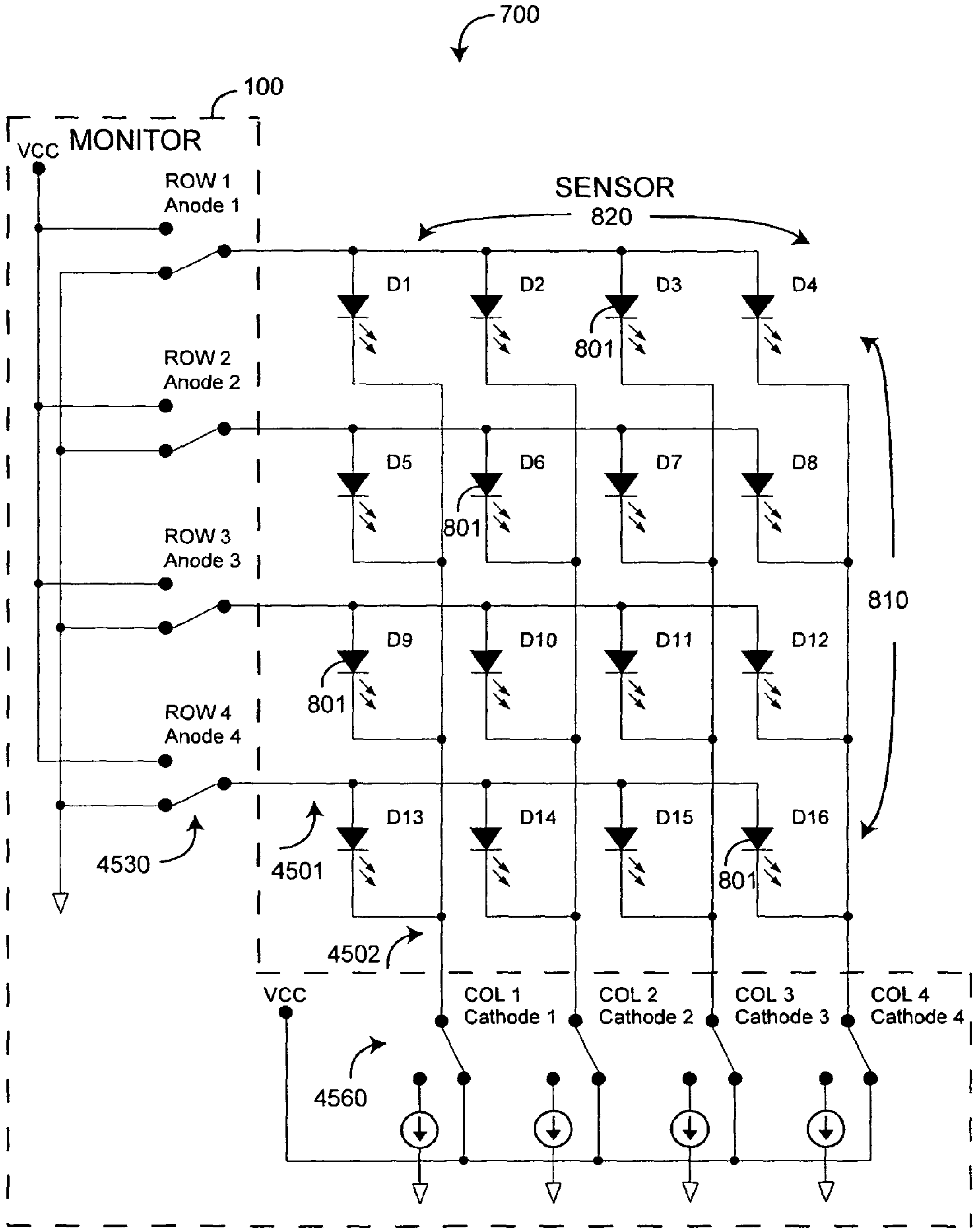

700
100
VCC MONITOR
ROW 1
Anode 1
SENSOR
820
D1
D2
D3
D4
801
ROW 2
Anode 2
D5
D6
D7
D8
801
ROW 3
Anode 3
810
D9
D10
D11
D12
801
ROW 4
Anode 4
D13
D14
D15
D16
4530
4501
801
4502
VCC
COL 1
Cathode 1
COL 2
Cathode 2
COL 3
Cathode 3
COL 4
Cathode 4
4560

FIG. 8

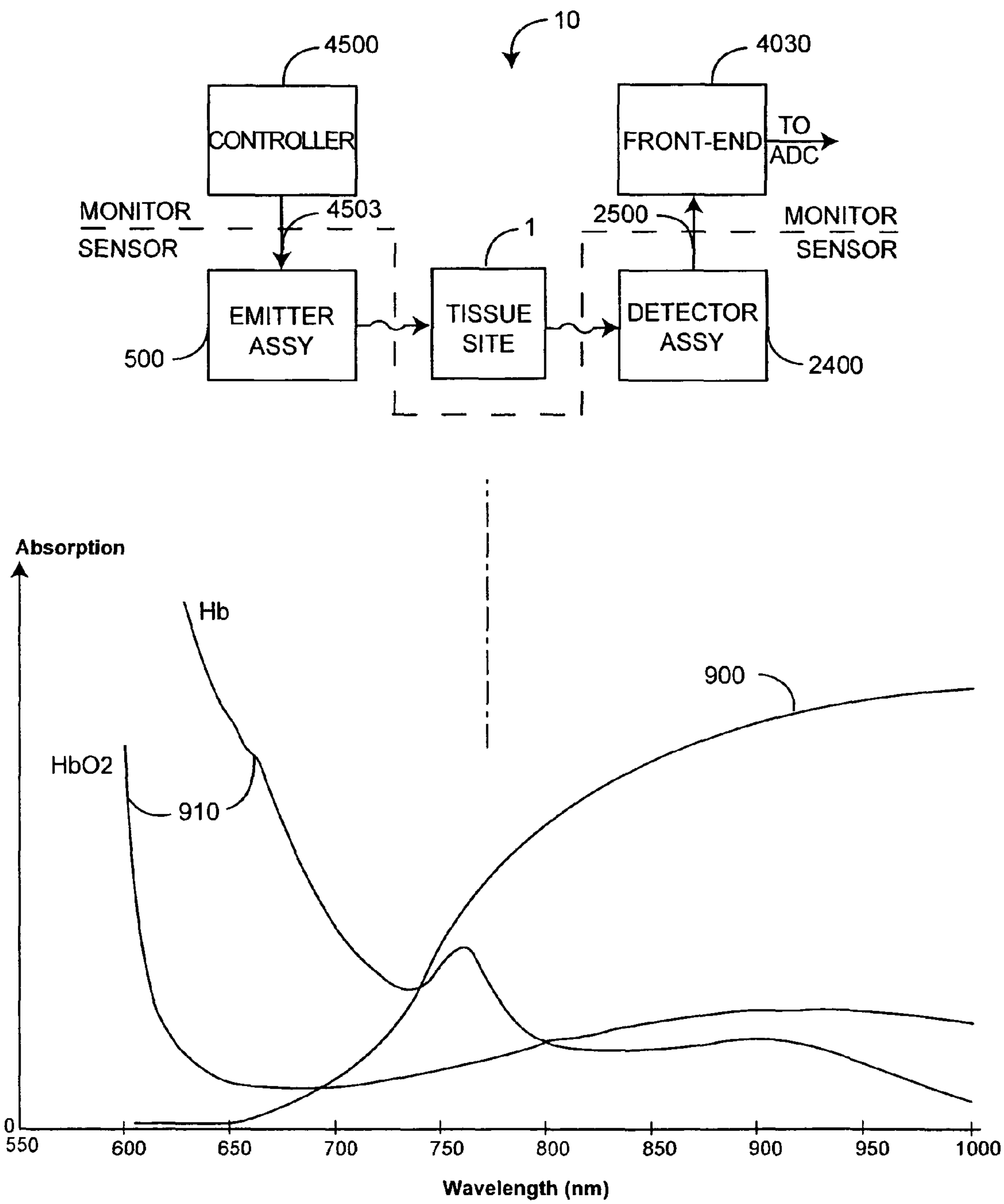

10
4500
CONTROLLER
4503
MONITOR
SENSOR
EMITTER ASSY
500
1
TISSUE SITE
4030
FRONT-END
TO ADC
2500
MONITOR
SENSOR
DETECTOR ASSY
2400
Absorption
Hb
HbO2
910
900
0
550
600
650
700
750
800
850
900
950
1000
Wavelength (nm)

FIG. 9

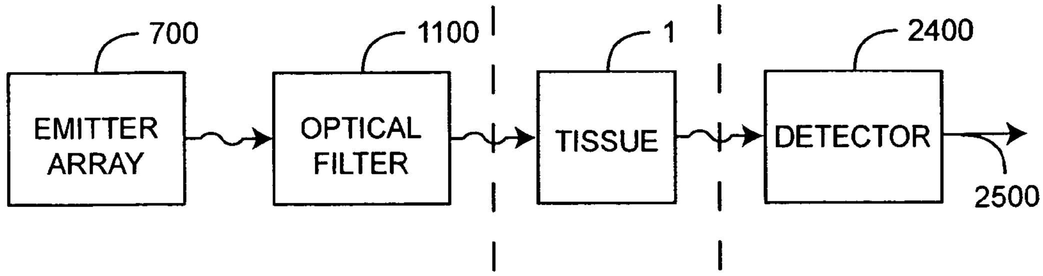


FIG. 10A

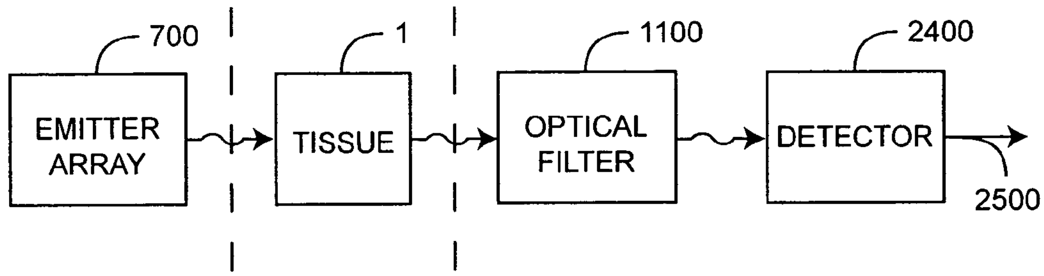


FIG. 10B

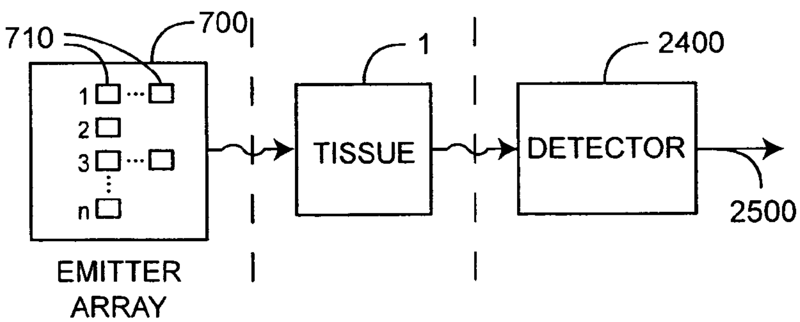


FIG. 10C

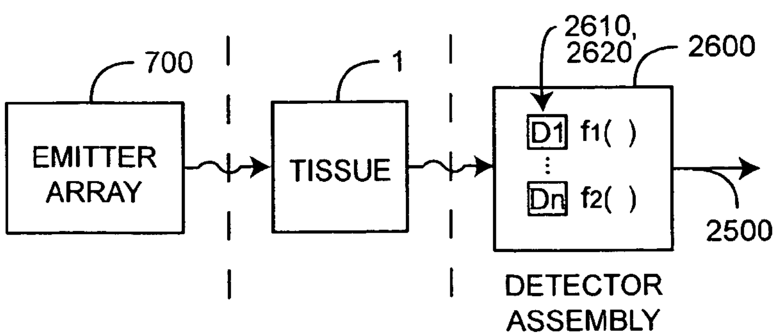


FIG. 10D

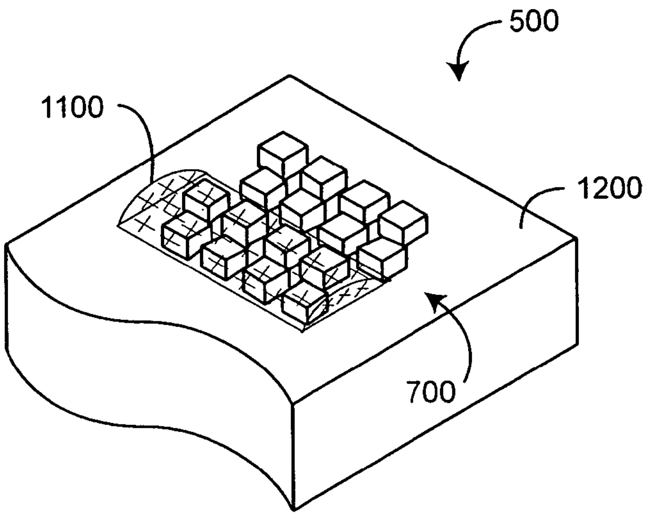


FIG. 11A

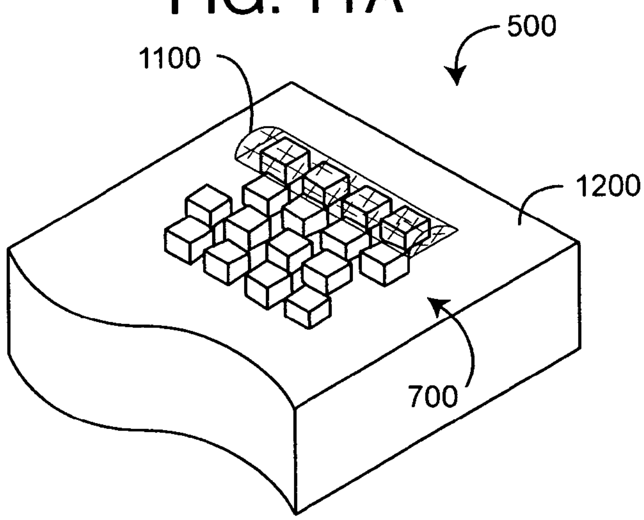


FIG. 11B

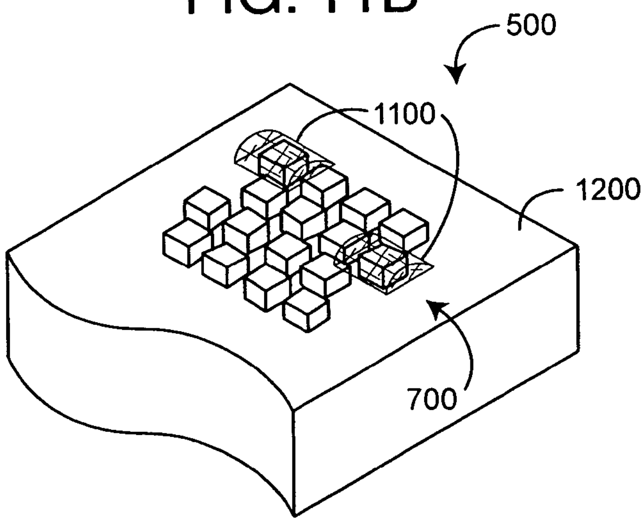


FIG. 11C

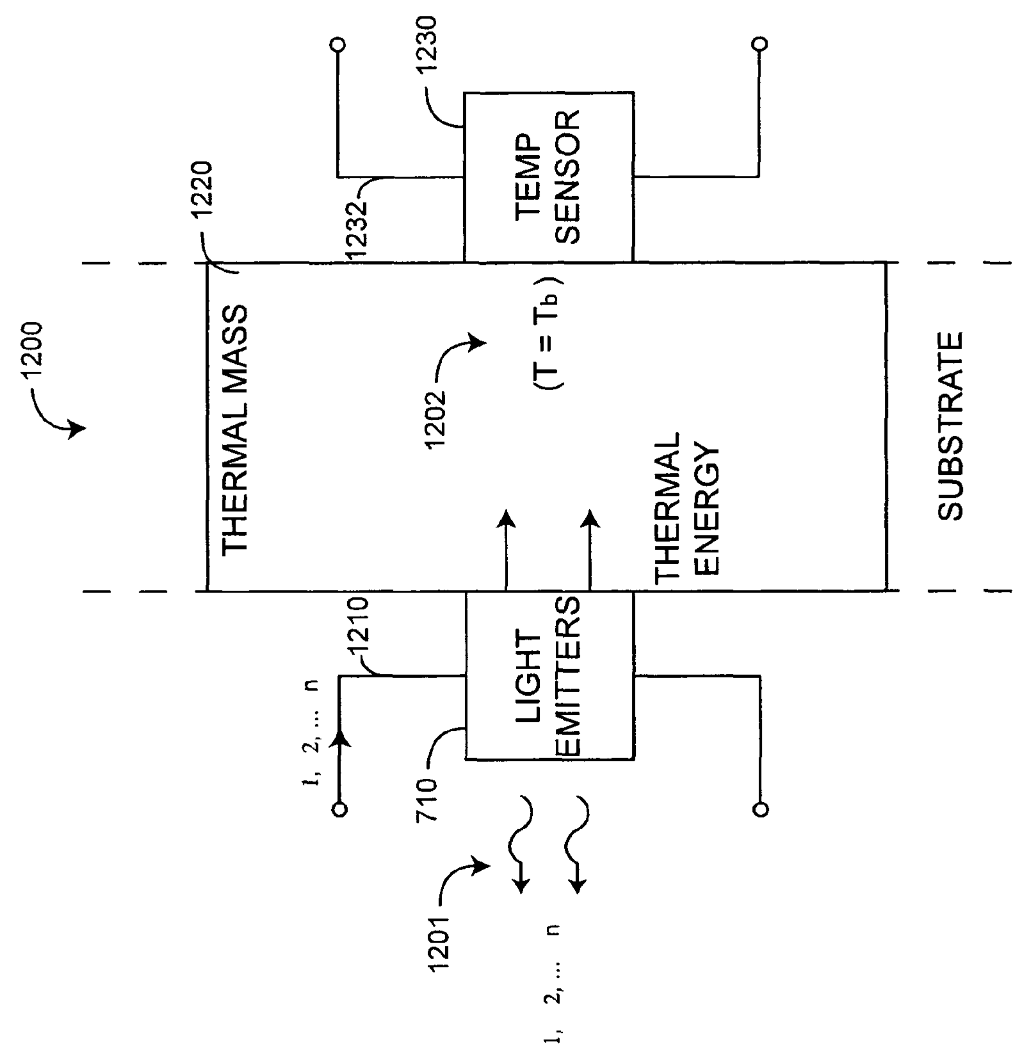

1200
THERMAL MASS
1220
1202
(T = Tb)
THERMAL ENERGY
SUBSTRATE
1230
TEMP SENSOR
1232
1210
LIGHT EMITTERS
710
1, 2, ... n
1201
1, 2, ... n

FIG. 12

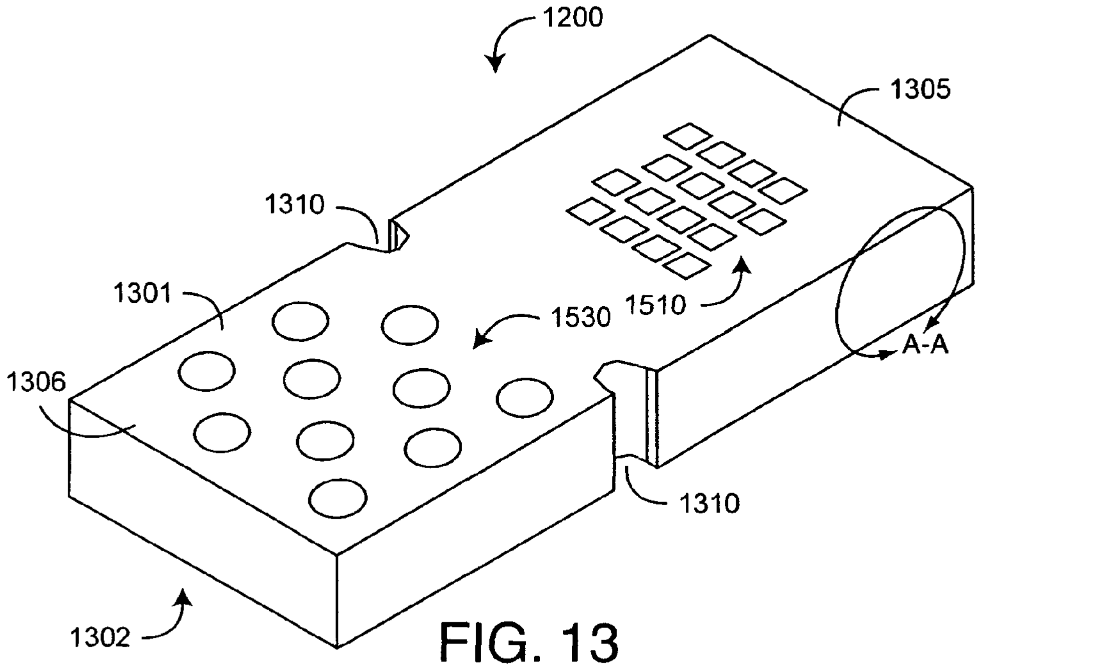

1200
1305
1310
1301
1530
1510
A-A
1306
1310
1302

FIG. 13

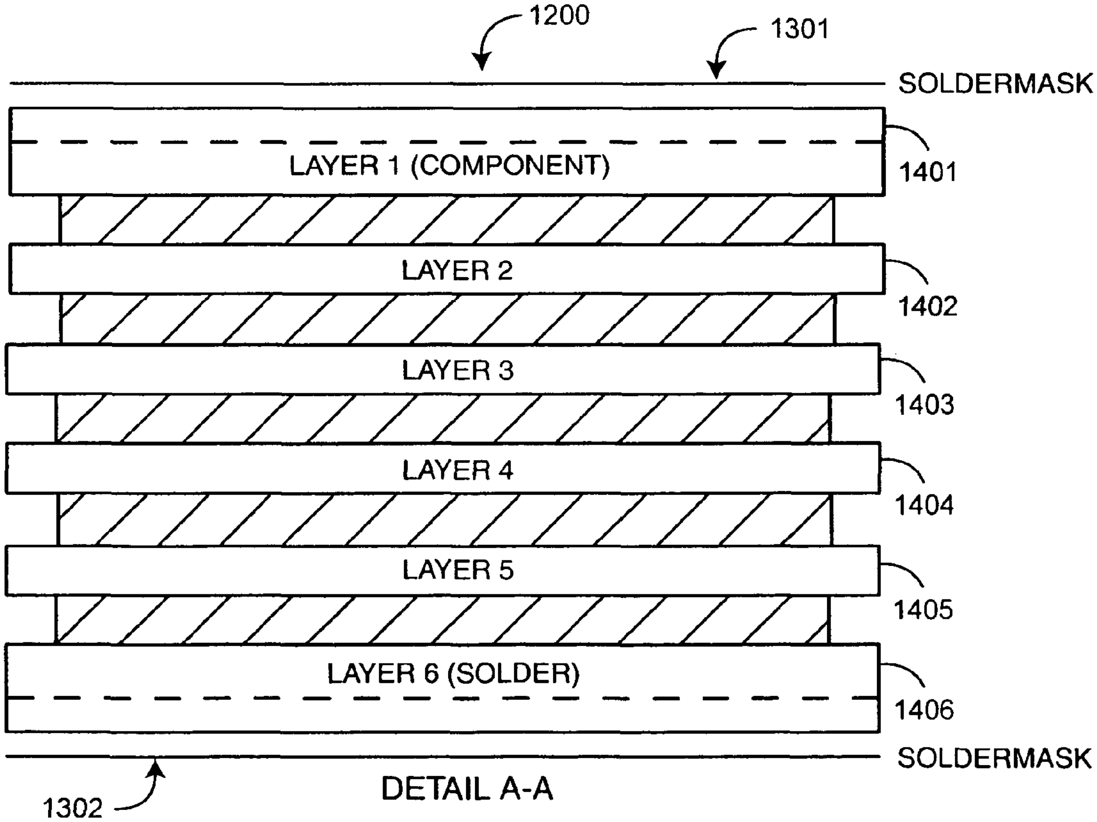
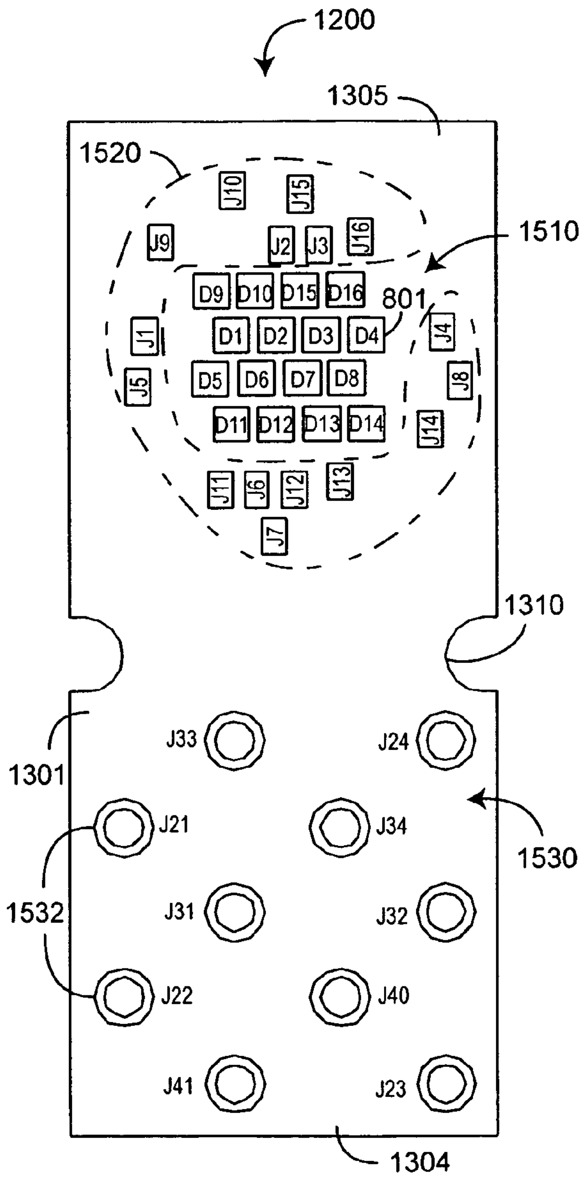
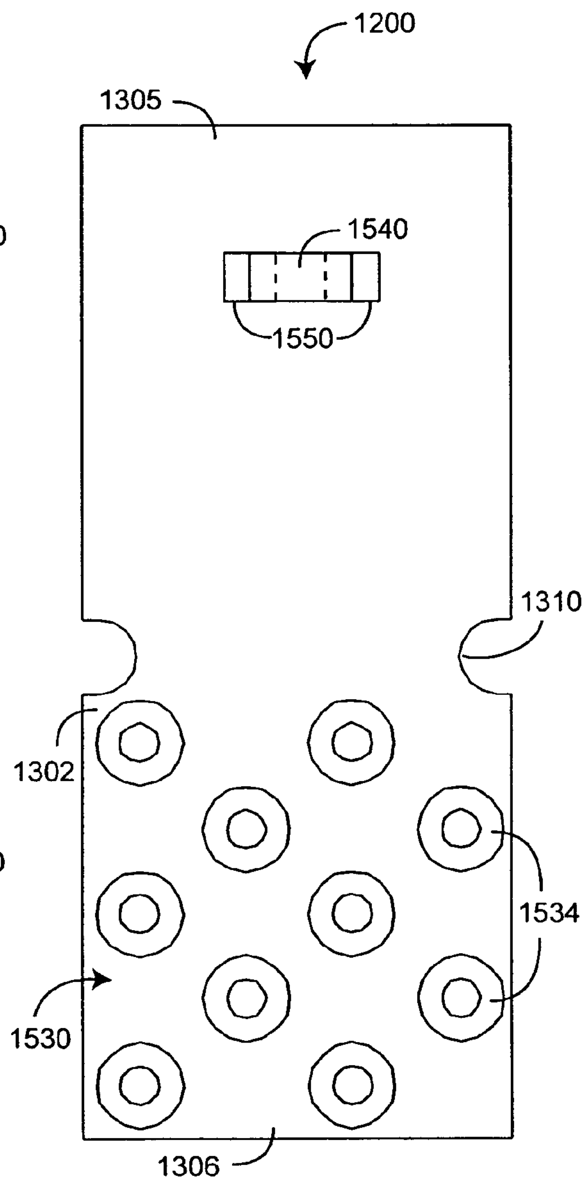

1200
1301
SOLDERMASK
LAYER 1 (COMPONENT)
1401
LAYER 2
1402
LAYER 3
1403
LAYER 4
1404
LAYER 5
1405
LAYER 6 (SOLDER)
1406
SOLDERMASK
1302
DETAIL A-A

FIG. 14



1200
1305
1520
1510
J10
J15
J9
J2
J3
J16
D9
D10
D15
D16
801
D1
D2
D3
D4
J1
J4
J5
D5
D6
D7
D8
J8
D11
D12
D13
D14
J14
J11
J6
J12
J13
J7
1310
1301
J33
J24
J21
J34
1530
1532
J31
J32
J22
J40
J41
J23
1304

FIG. 15



1200
1305
1540
1550
1310
1302
1534
1530
1306

FIG. 16

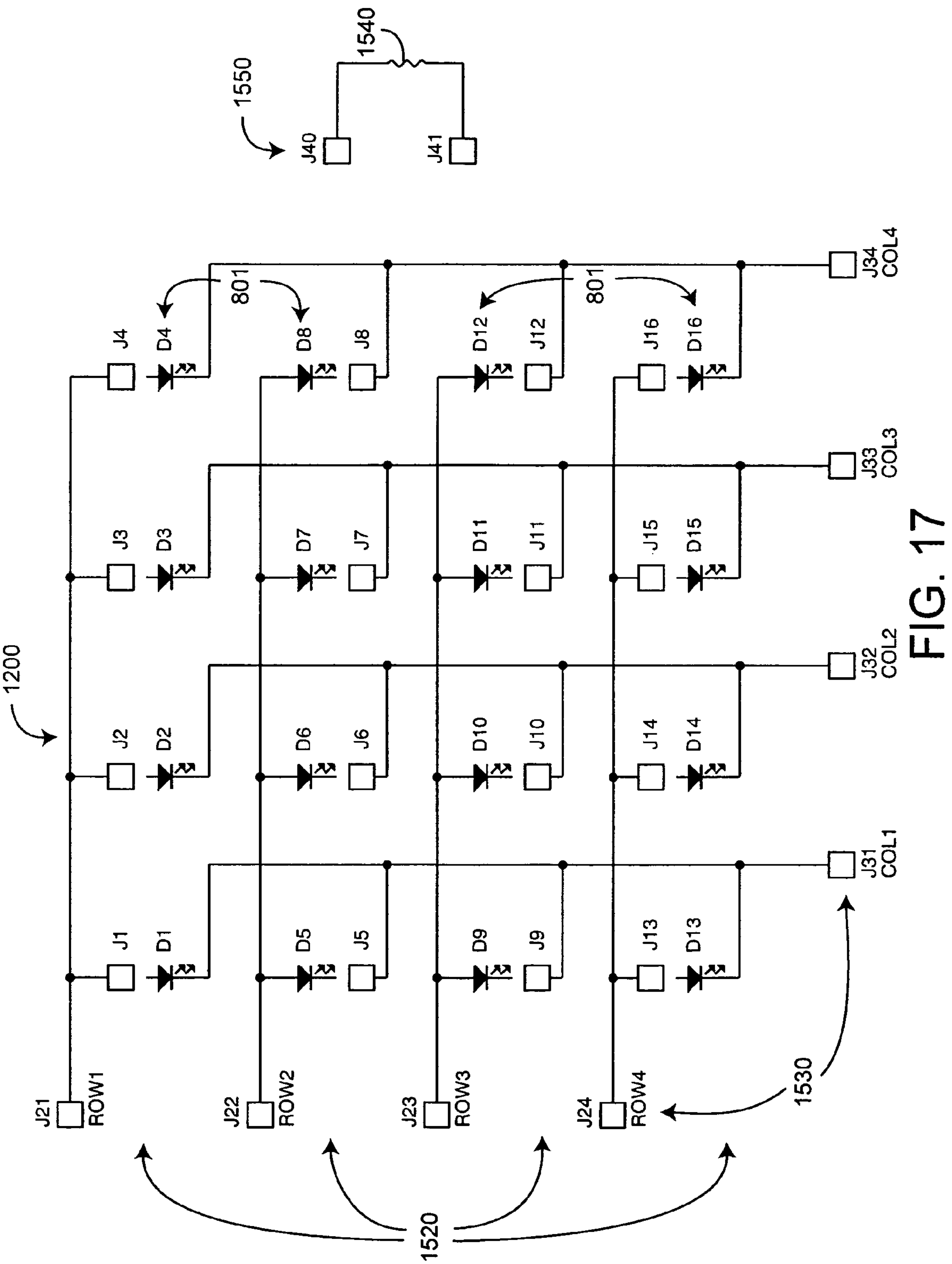

1550
1540
J40
J41
1200
801
801
J1 J2 J3 J4
D1 D2 D3 D4
D5 D6 D7 D8
J5 J6 J7 J8
D9 D10 D11 D12
J9 J10 J11 J12
J13 J14 J15 J16
D13 D14 D15 D16
J21 ROW1
J22 ROW2
J23 ROW3
J24 ROW4
J31 COL1
J32 COL2
J33 COL3
J34 COL4
1520
1530

FIG. 17

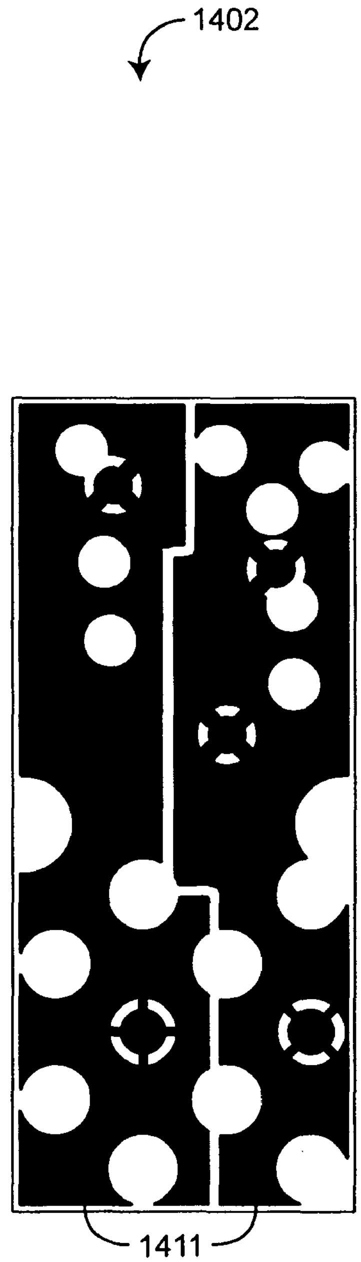


FIG. 18

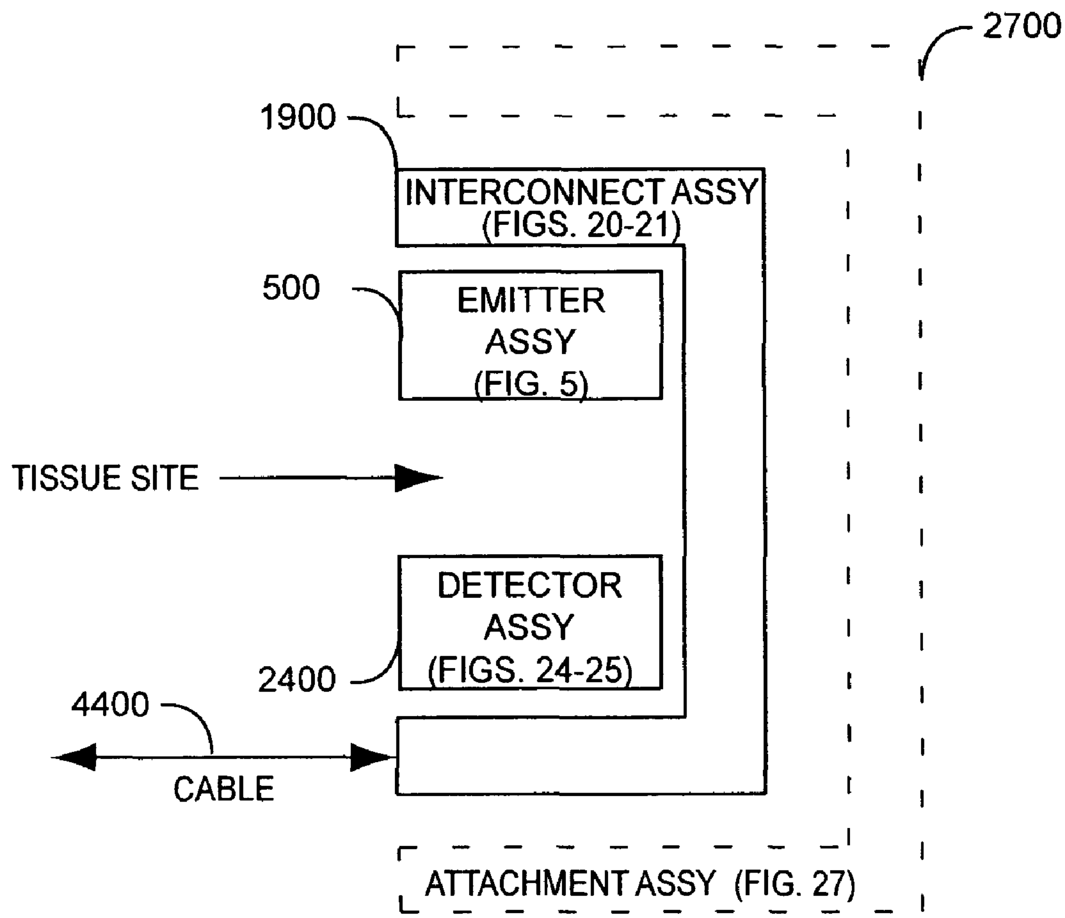

2700
1900
INTERCONNECT ASSY
(FIGS. 20-21)
500
EMITTER
ASSY
(FIG. 5)
TISSUE SITE
DETECTOR
ASSY
(FIGS. 24-25)
2400
4400
CABLE
ATTACHMENT ASSY (FIG. 27)

FIG. 19

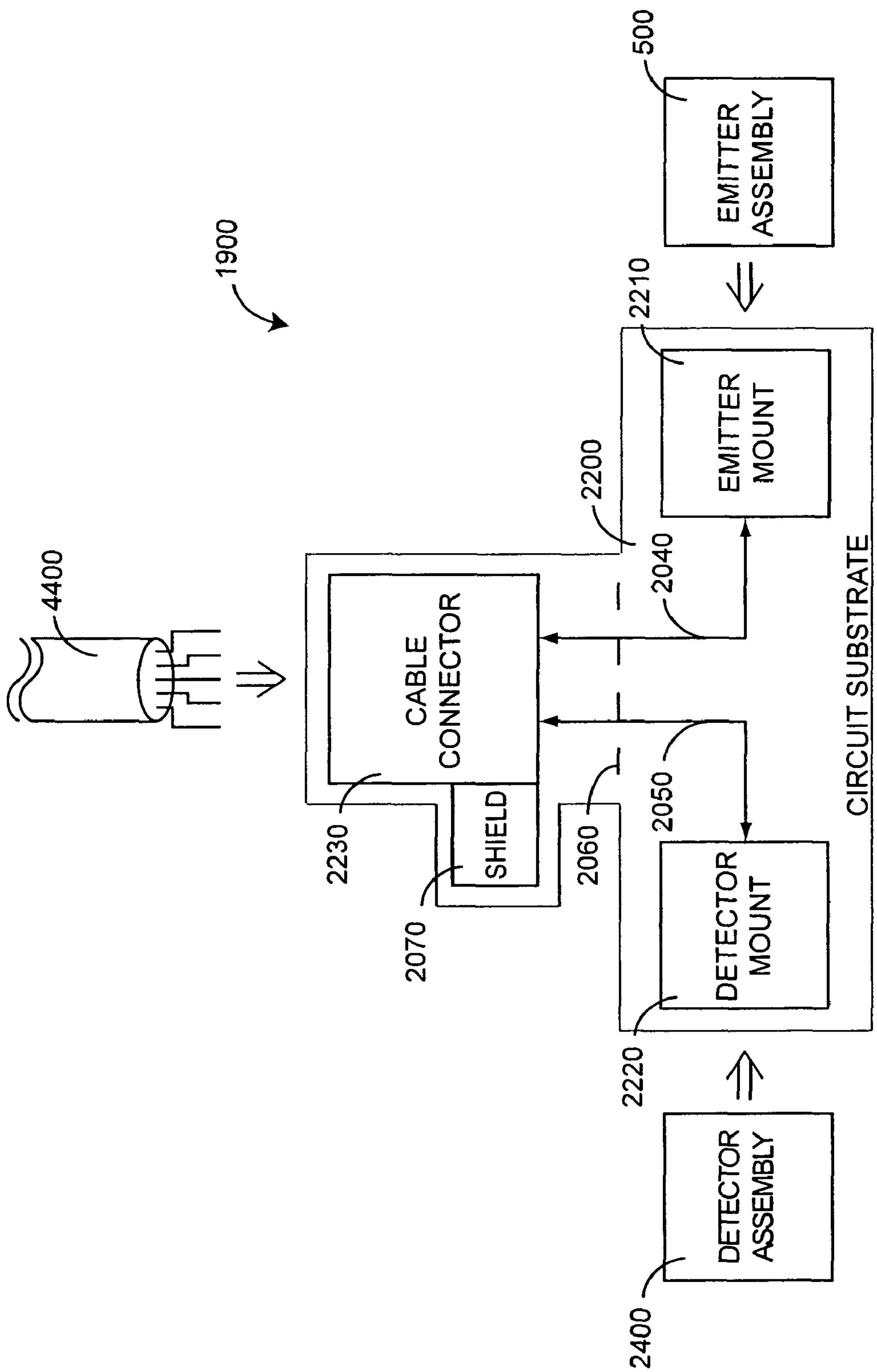

1900
500
EMITTER ASSEMBLY
2210
EMITTER MOUNT
2200
4400
2040
CABLE CONNECTOR
CIRCUIT SUBSTRATE
2230
SHIELD
2060
2050
2070
DETECTOR MOUNT
2220
DETECTOR ASSEMBLY
2400

FIG. 20

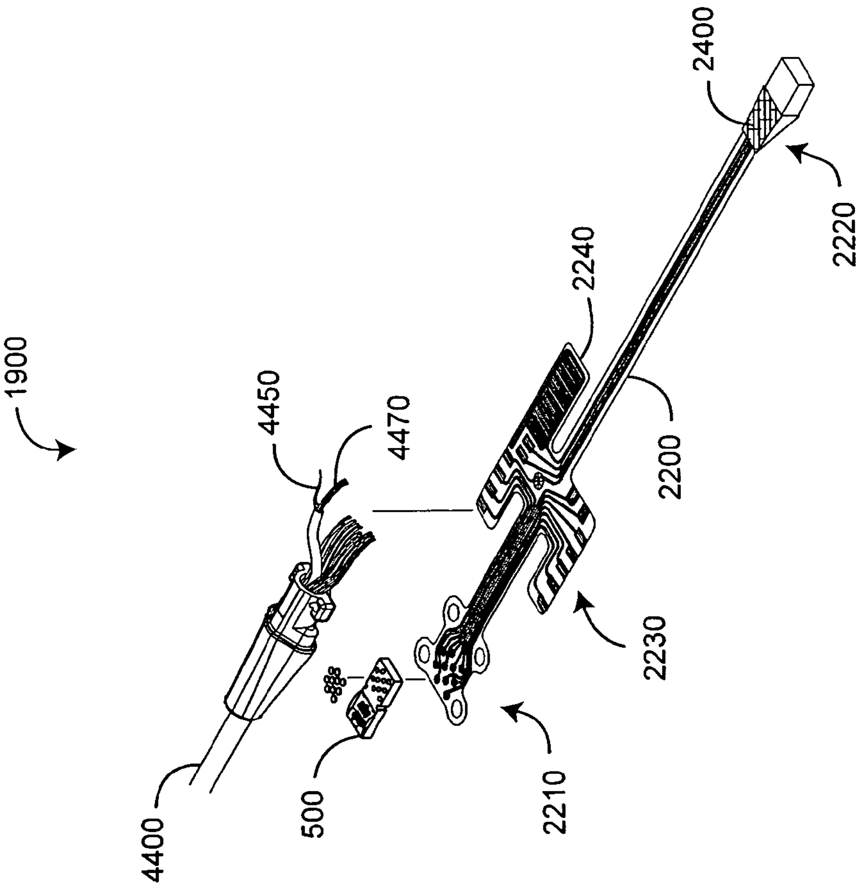


FIG. 21

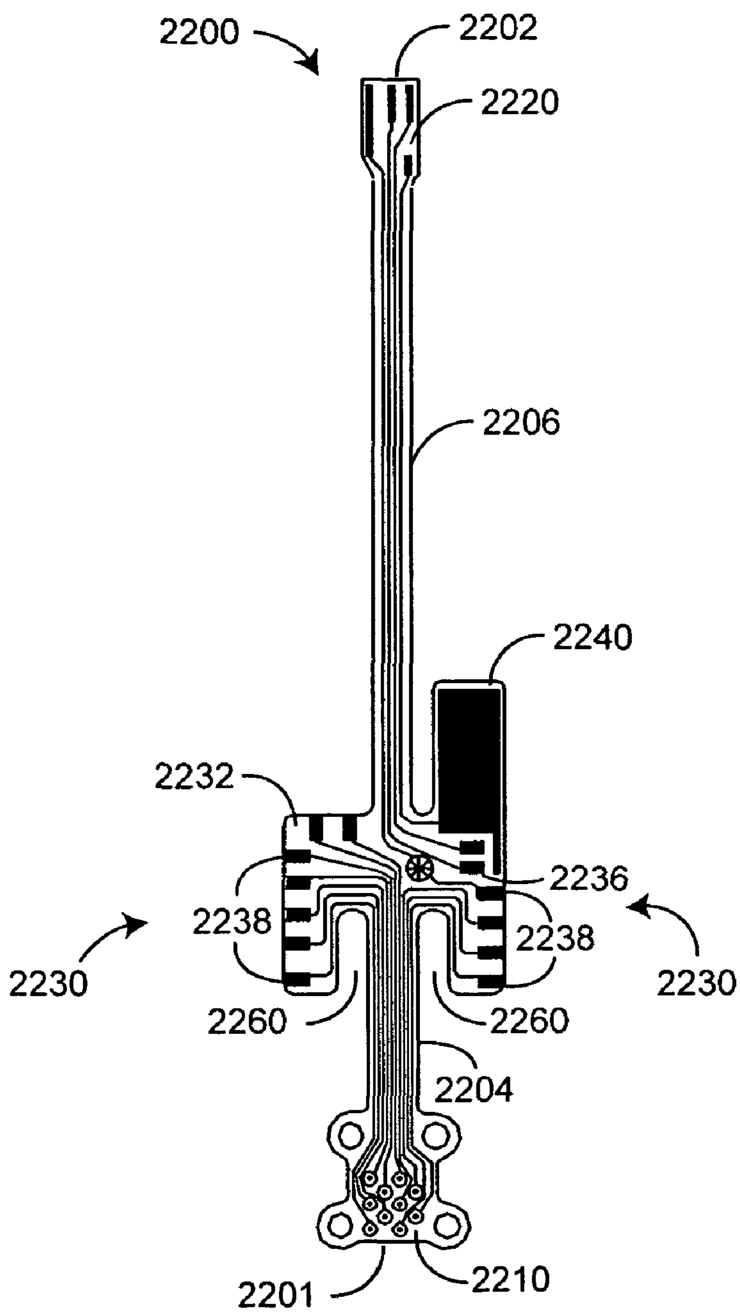

2200
2202
2220
2206
2240
2232
2236
2238
2238
2230
2230
2260
2260
2204
2201
2210

FIG. 22

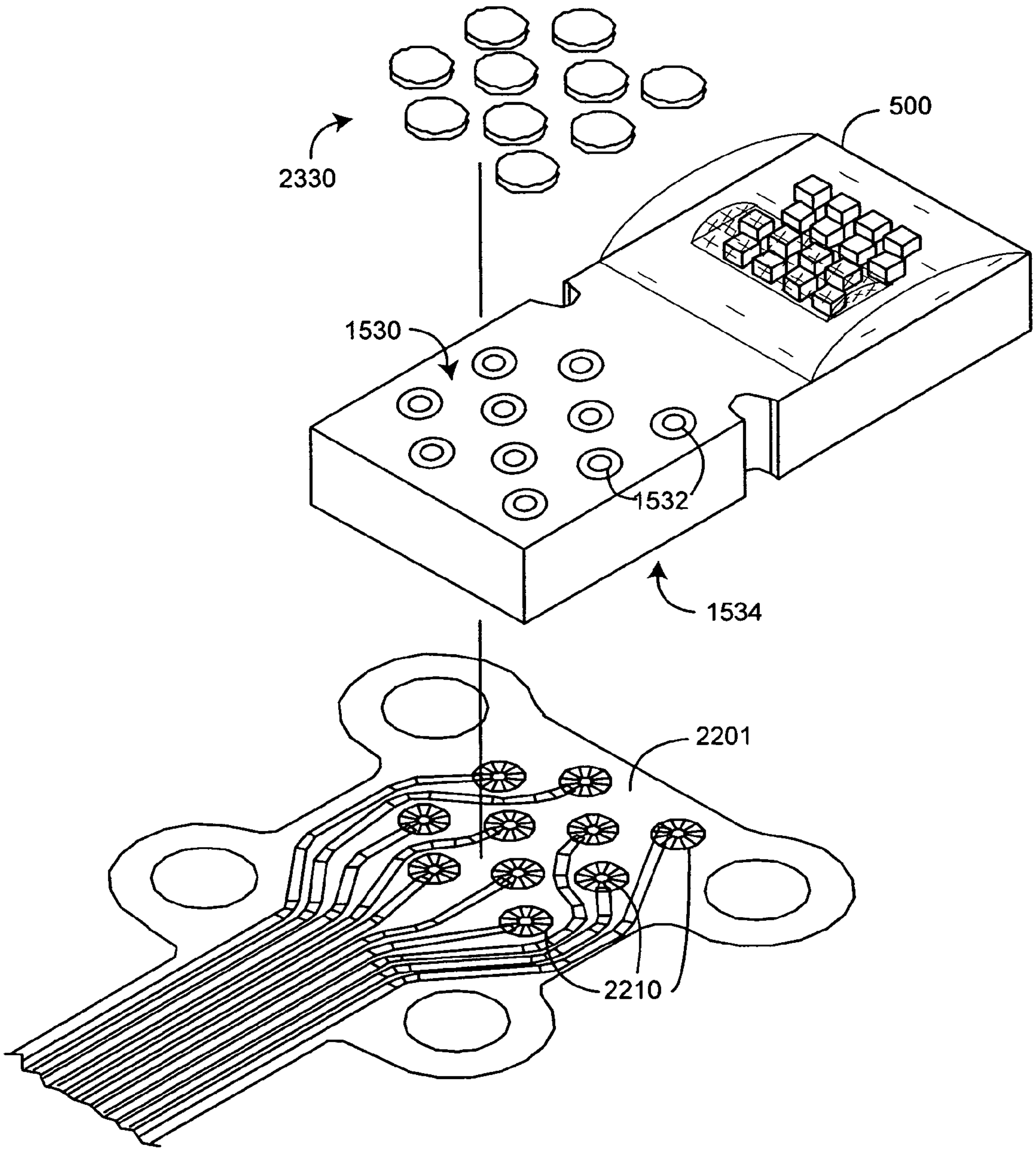


FIG. 23

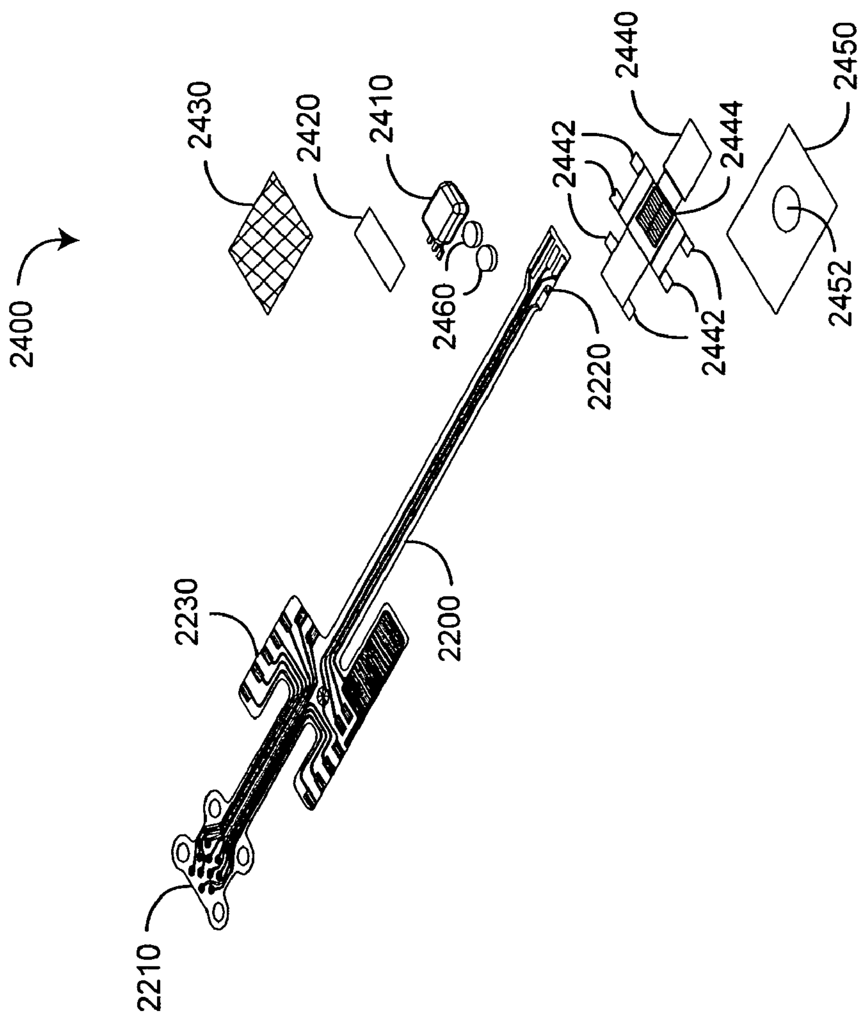

2400
2430
2420
2410
2460
2440
2442
2444
2442
2450
2452
2220
2230
2200
2210

FIG. 24

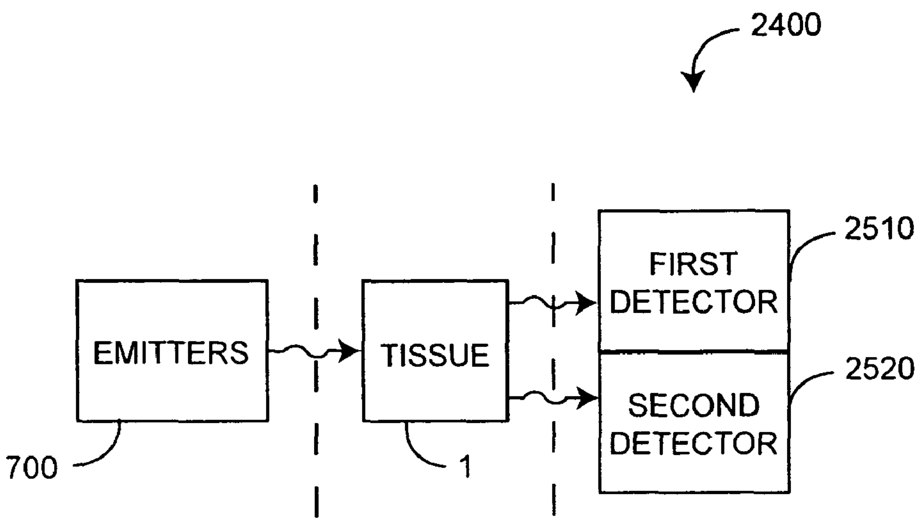

2400
EMITTERS
TISSUE
FIRST DETECTOR
SECOND DETECTOR
2510
2520
700
1

FIG. 25

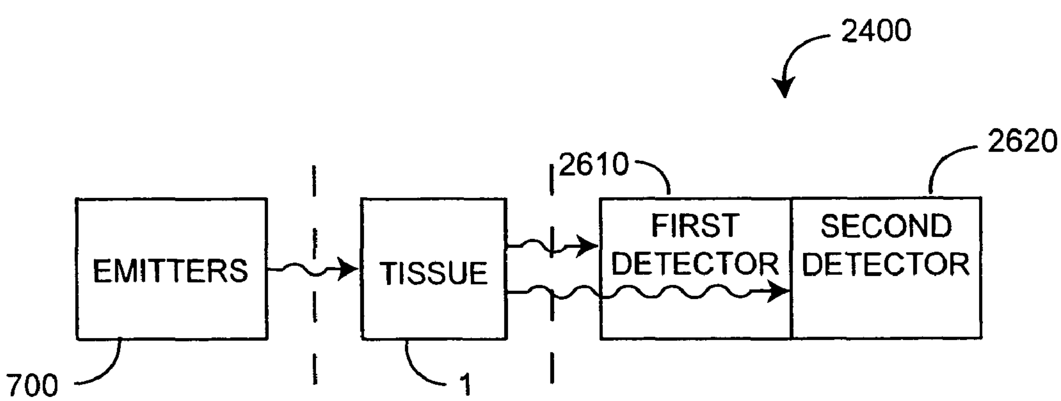

2400
2610
2620
EMITTERS
TISSUE
FIRST DETECTOR
SECOND DETECTOR
700
1

FIG. 26

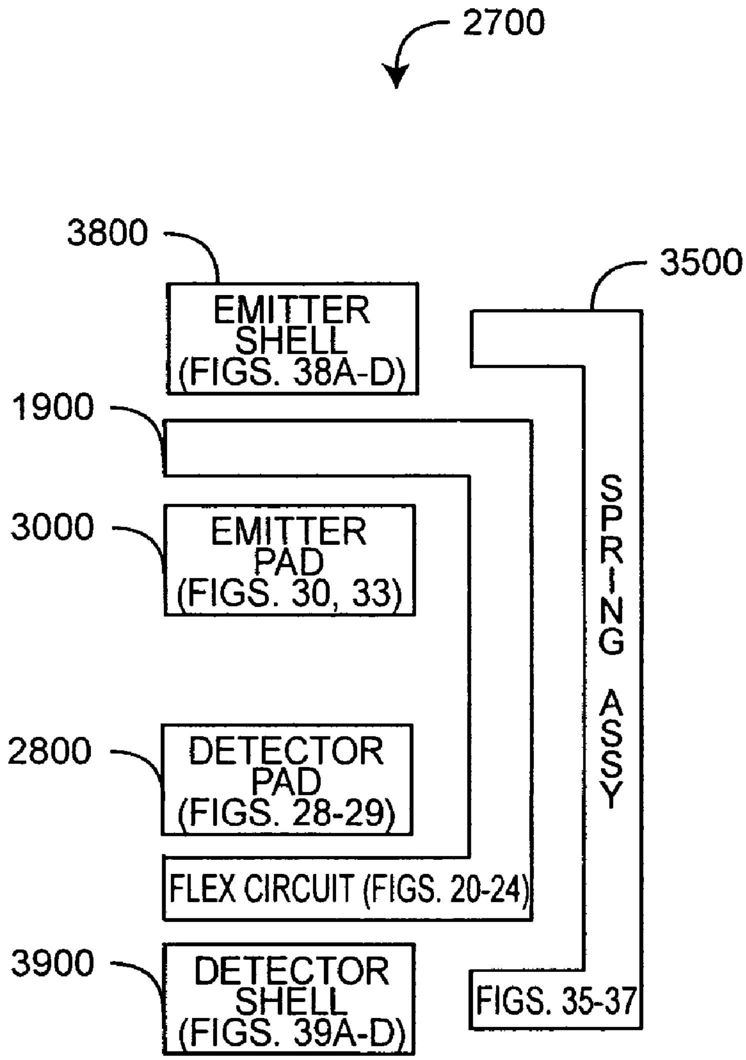

2700
3800
EMITTER SHELL (FIGS. 38A-D)
3500
1900
3000
EMITTER PAD (FIGS. 30, 33)
SPRING ASSY
2800
DETECTOR PAD (FIGS. 28-29)
FLEX CIRCUIT (FIGS. 20-24)
3900
DETECTOR SHELL (FIGS. 39A-D)
FIGS. 35-37

FIG. 27

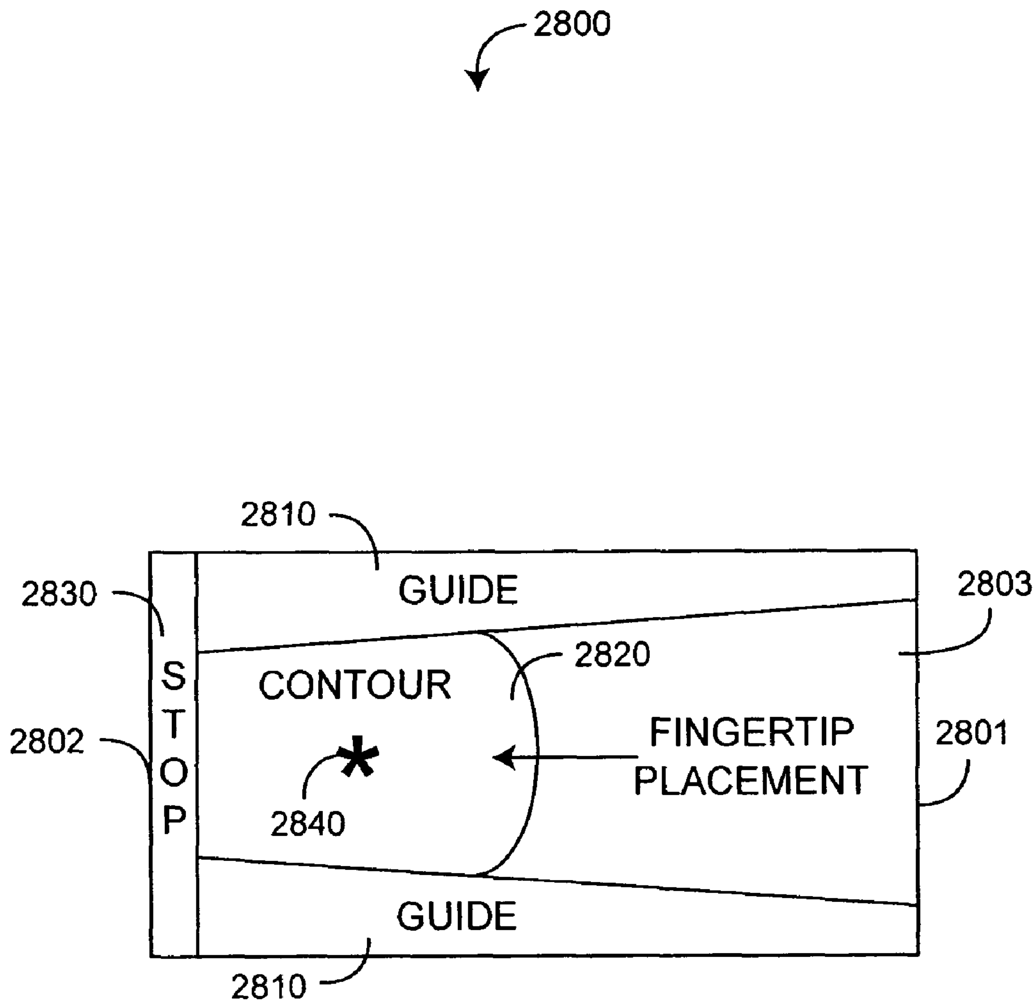

2800
2810
GUIDE
2830
2803
S
T
O
P
CONTOUR
2820
FINGERTIP
PLACEMENT
2802
2801
*
2840
GUIDE
2810

FIG. 28

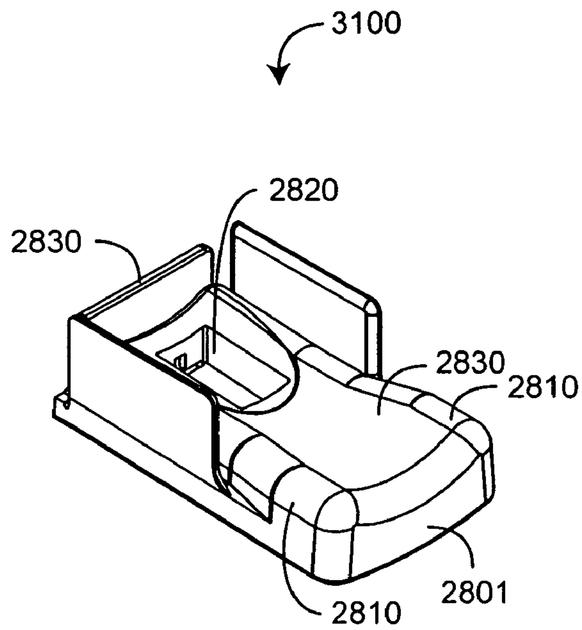


FIG. 29A

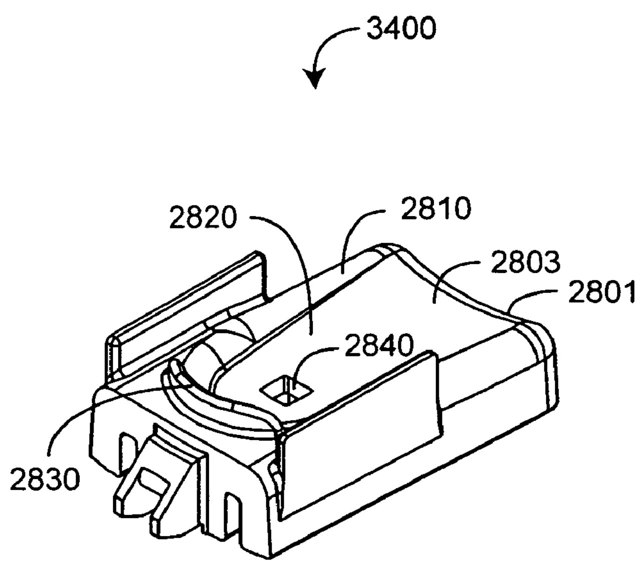


FIG. 29B

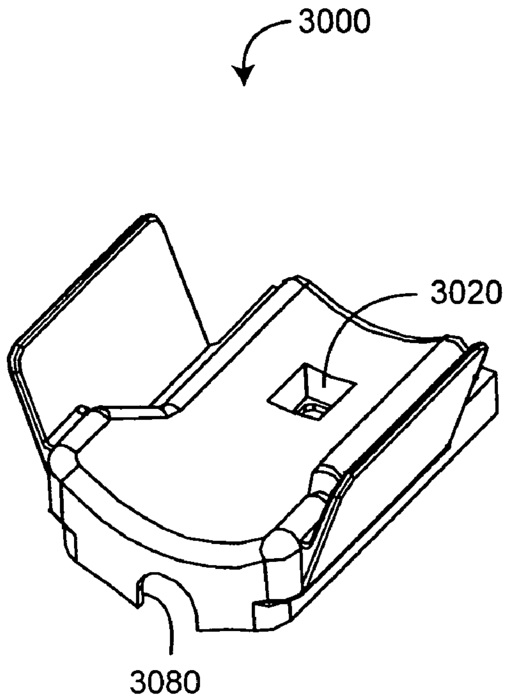


FIG. 30A

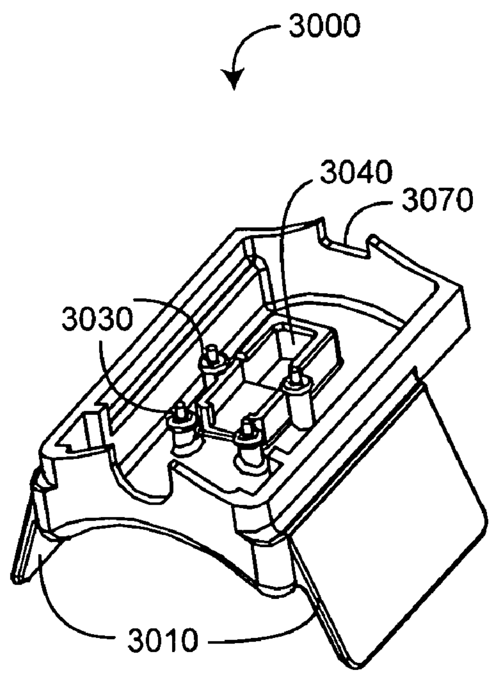


FIG. 30B

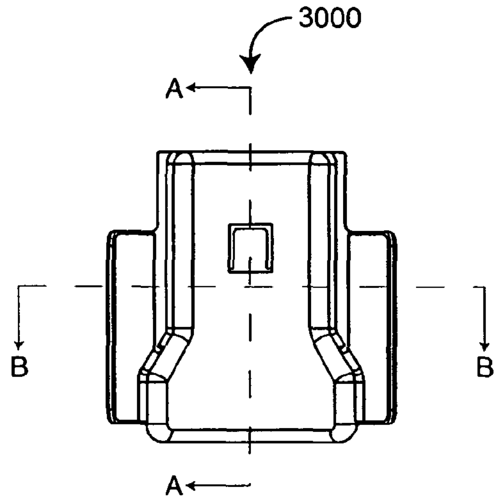


FIG. 30C

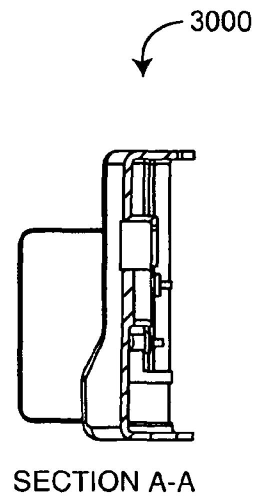


FIG. 30F

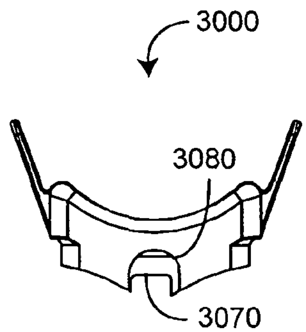


FIG. 30D

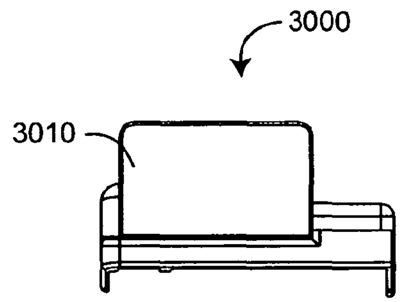


FIG. 30G

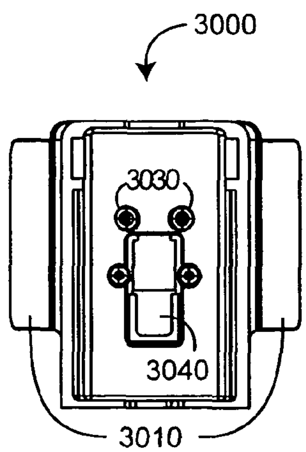


FIG. 30E

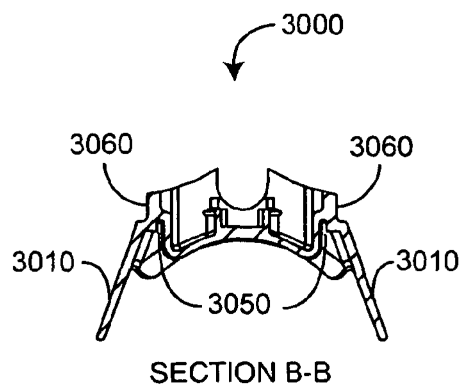


FIG. 30H

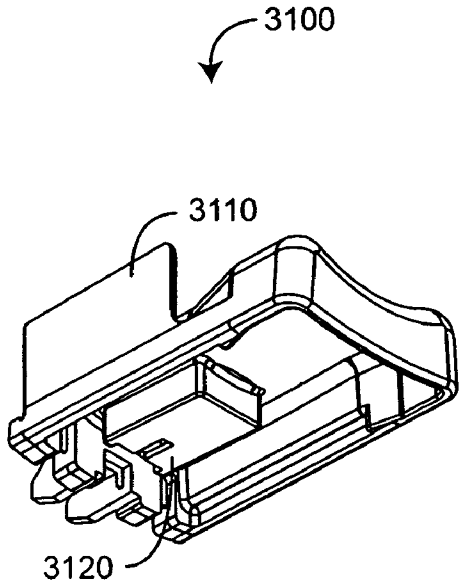


FIG. 31A

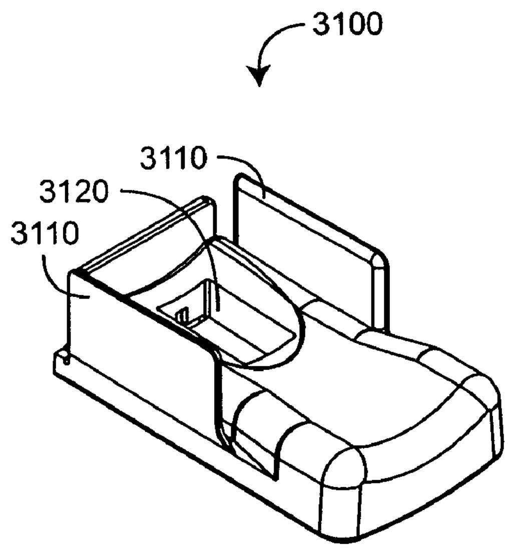


FIG. 31B

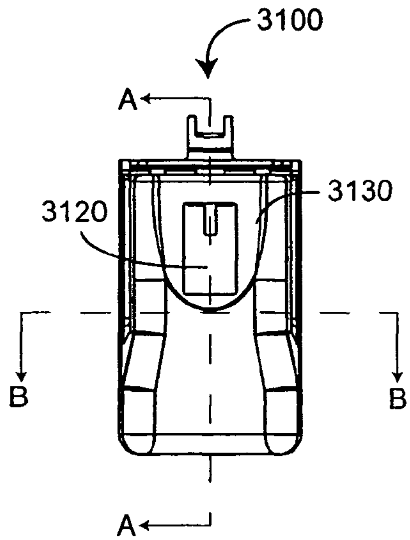
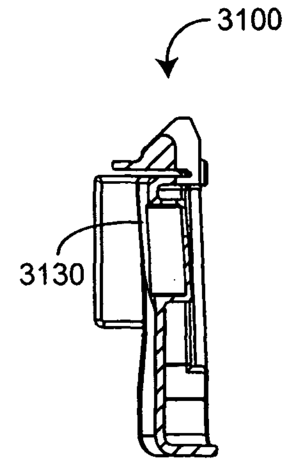


FIG. 31C



SECTION A-A

FIG. 31F

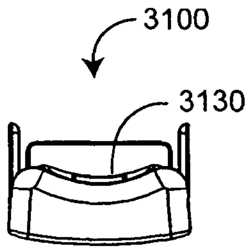


FIG. 31D

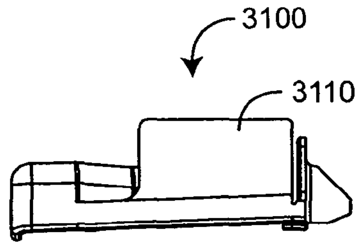


FIG. 31G

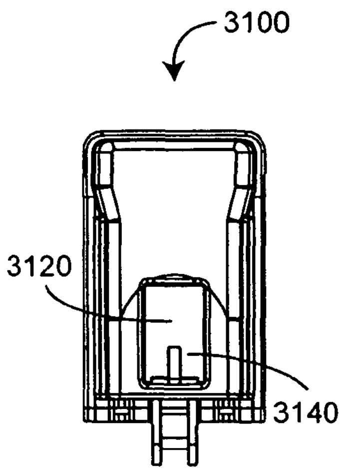
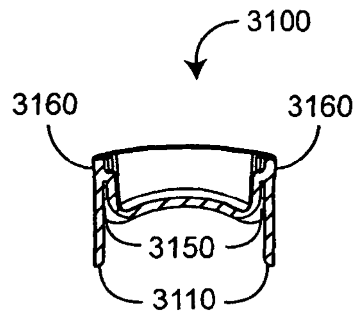


FIG. 31E



SECTION B-B

FIG. 31H

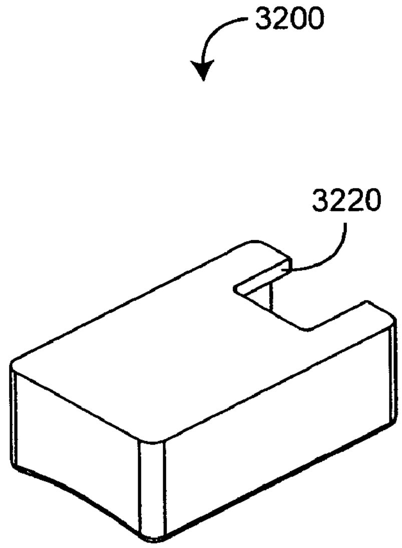


FIG. 32A

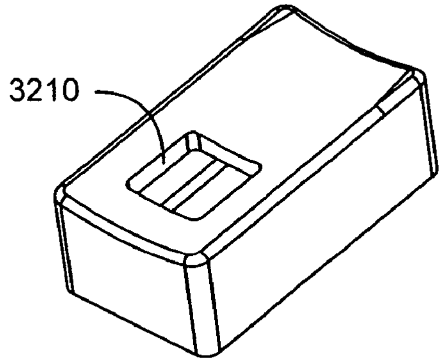


FIG. 32B

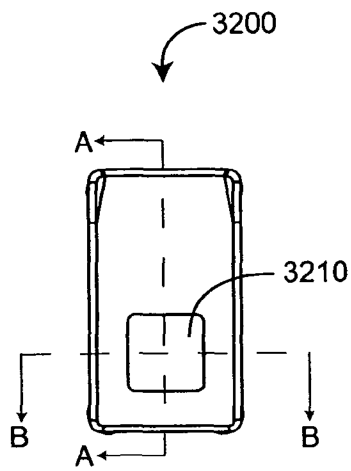


FIG. 32C

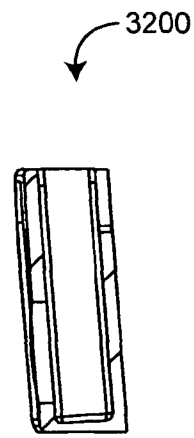


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FIG. 32F

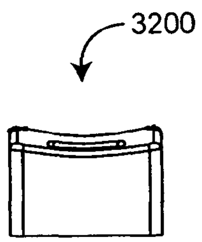

FIG. 32D

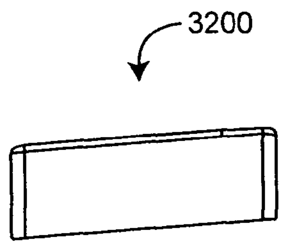

FIG. 32G

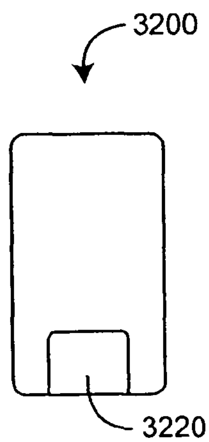

FIG. 32E

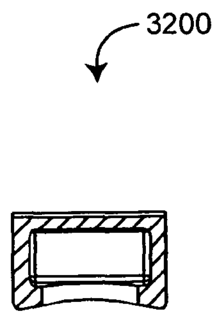

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FIG. 32H

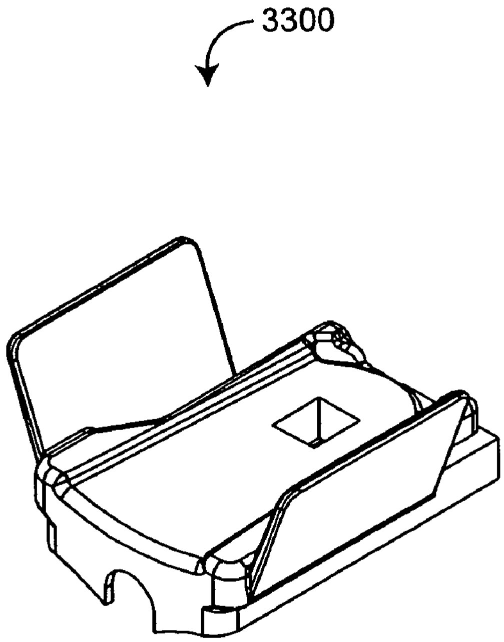

FIG. 33A

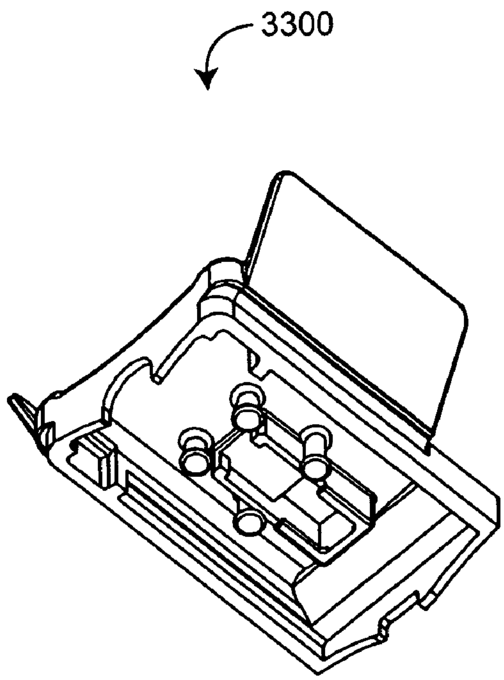

FIG. 33B

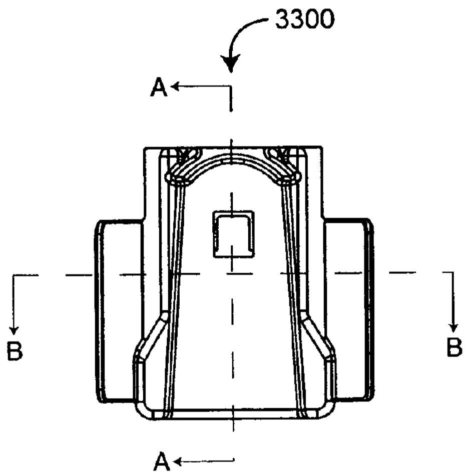

FIG. 33C

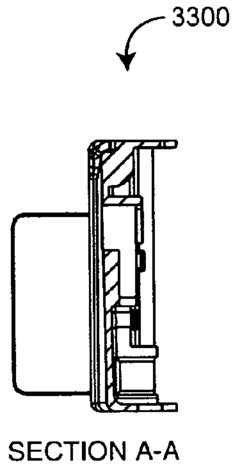

FIG. 33F

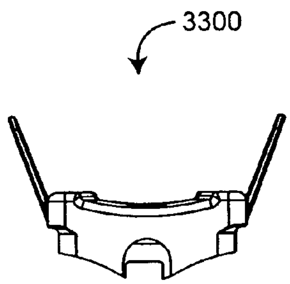

FIG. 33D

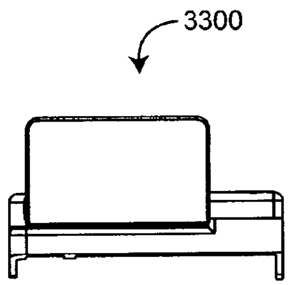

FIG. 33G

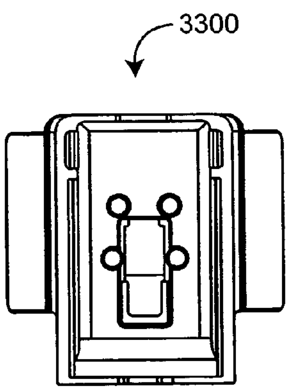

FIG. 33E

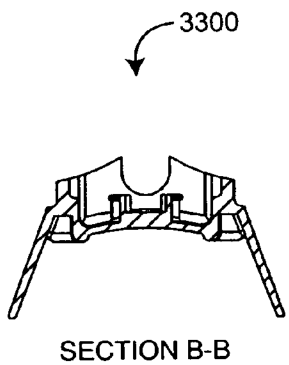

FIG. 33H

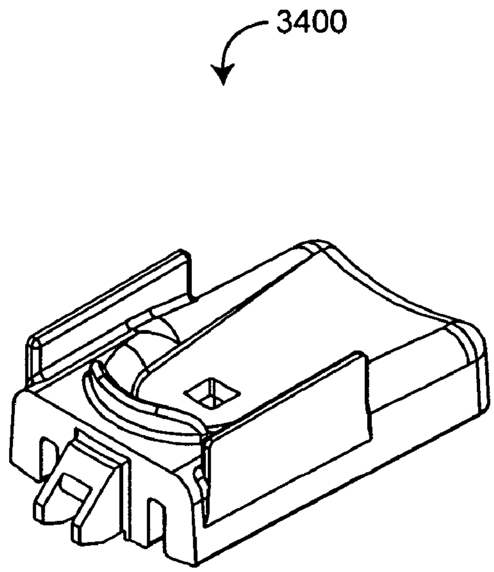

FIG. 34A

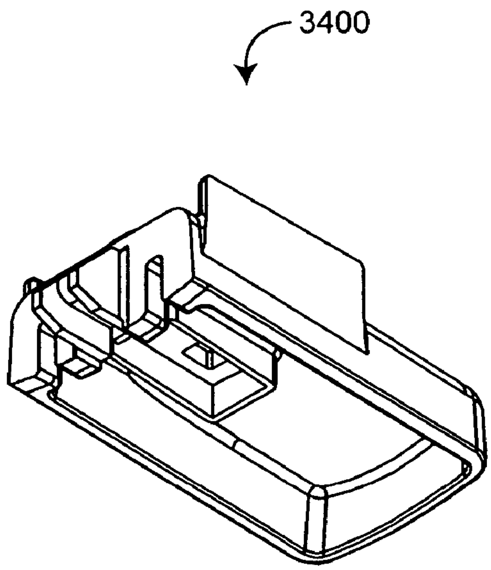

FIG. 34B

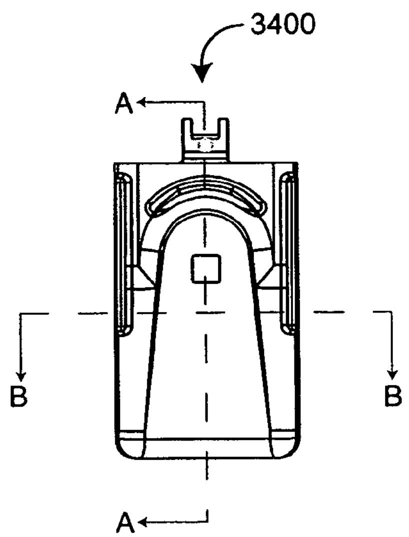

FIG. 34C

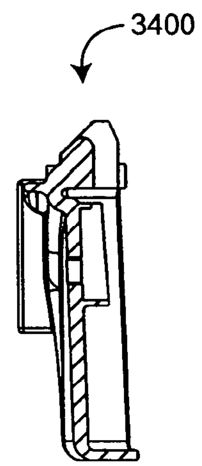

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FIG. 34F

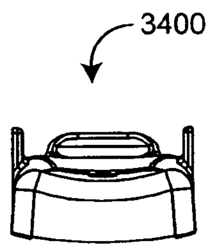

FIG. 34D

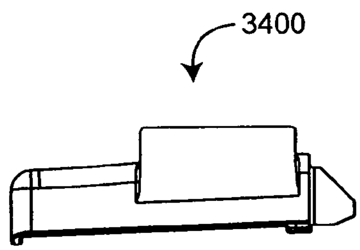

FIG. 34G

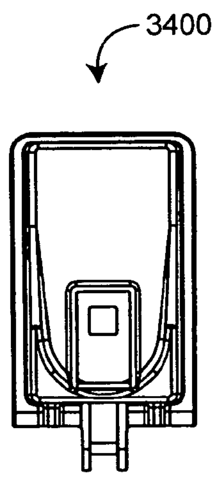

FIG. 34E

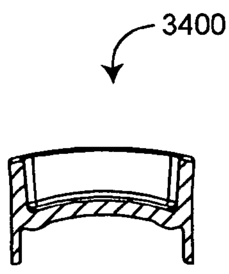

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FIG. 34H

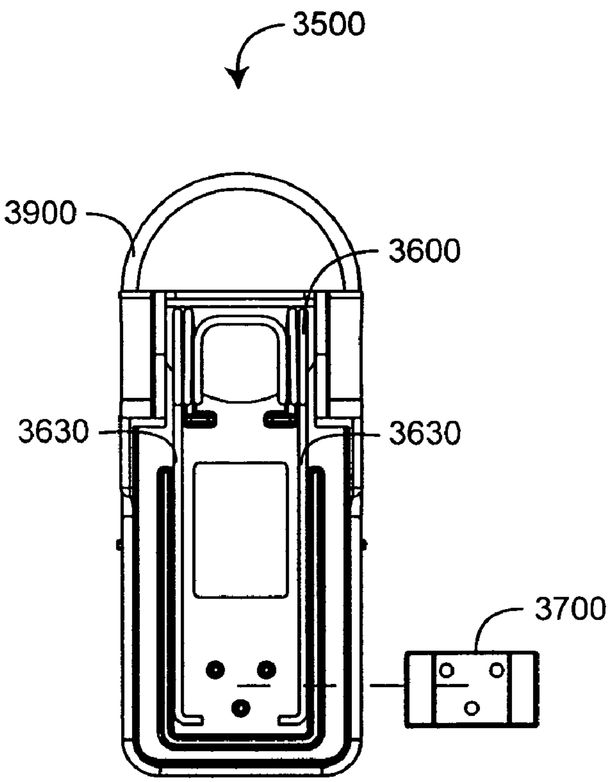

FIG. 35A

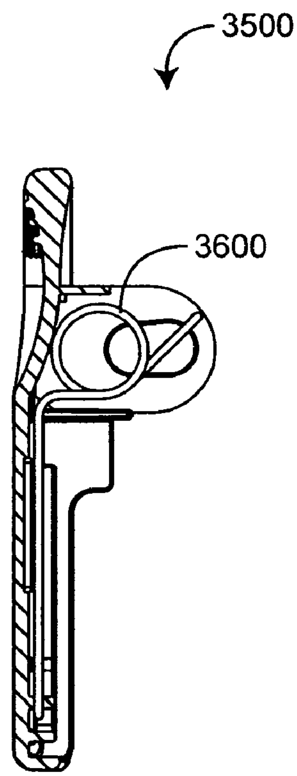

FIG. 35B

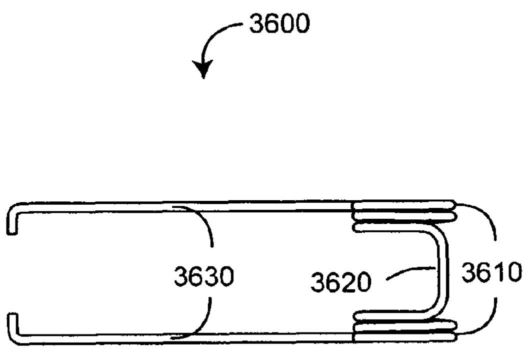

FIG. 36A

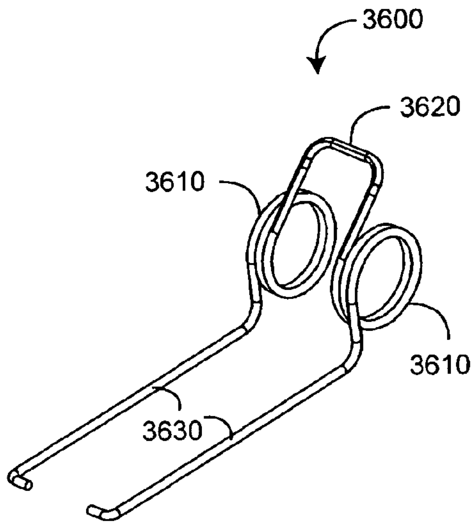

FIG. 36B

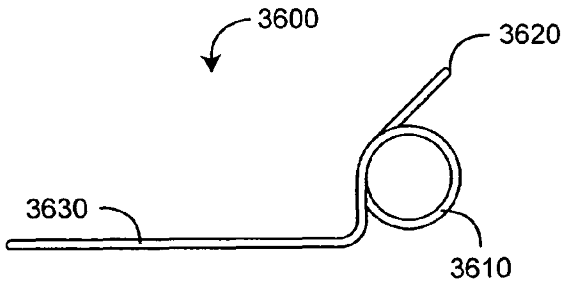

FIG. 36C

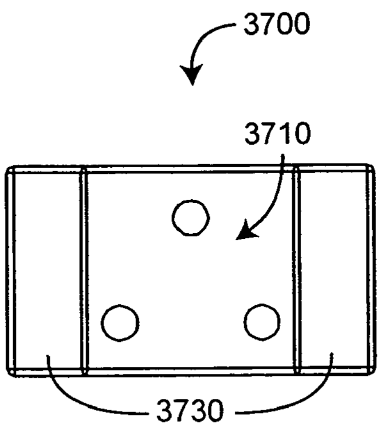

FIG. 37A

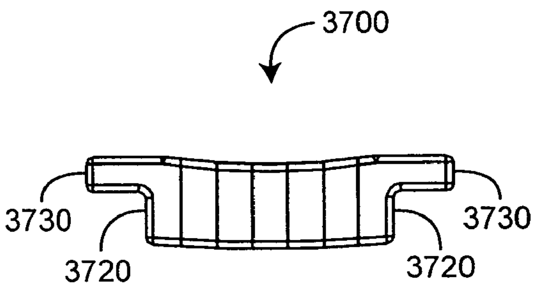

FIG. 37B

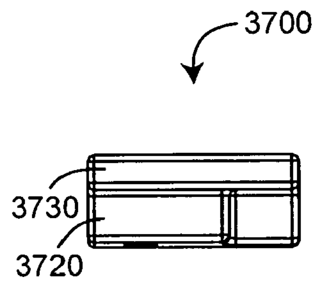

FIG. 37D

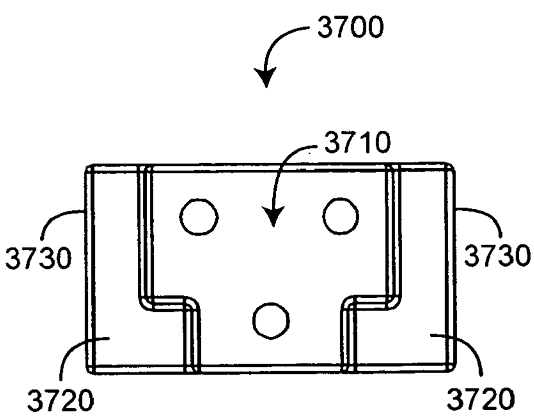

FIG. 37C

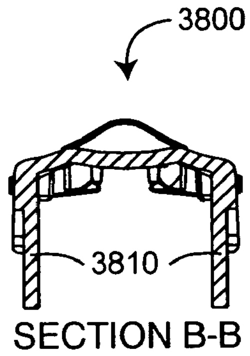

FIG. 38A

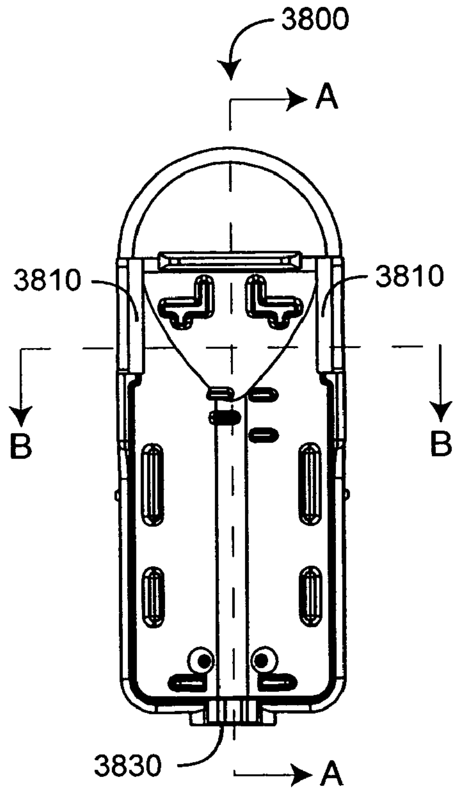

FIG. 38B

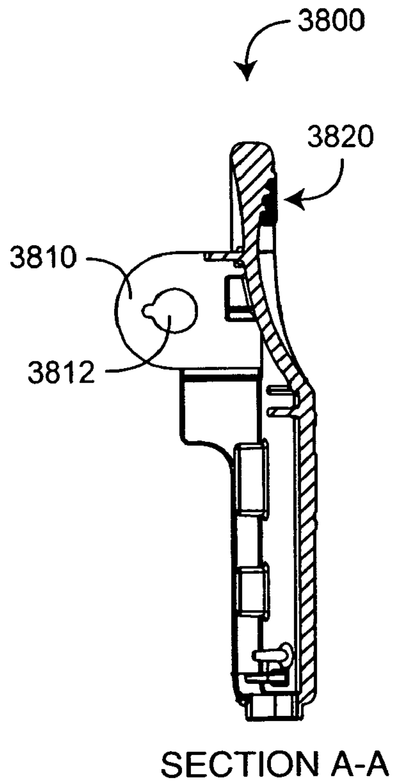

FIG. 38D

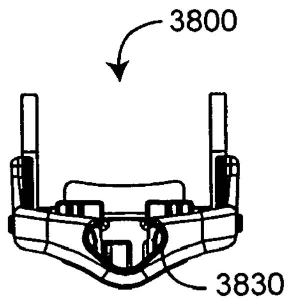

FIG. 38C

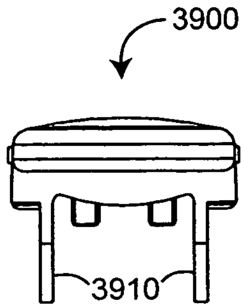

FIG. 39A

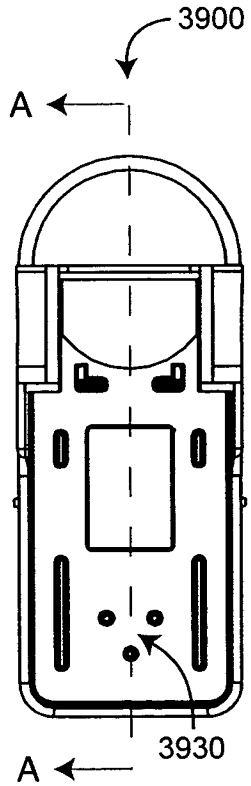

FIG.39B

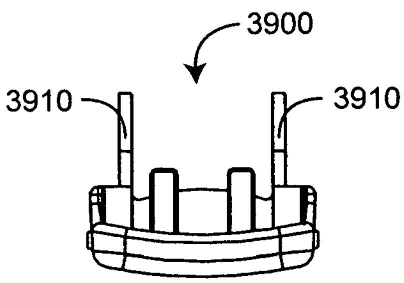

FIG. 39C

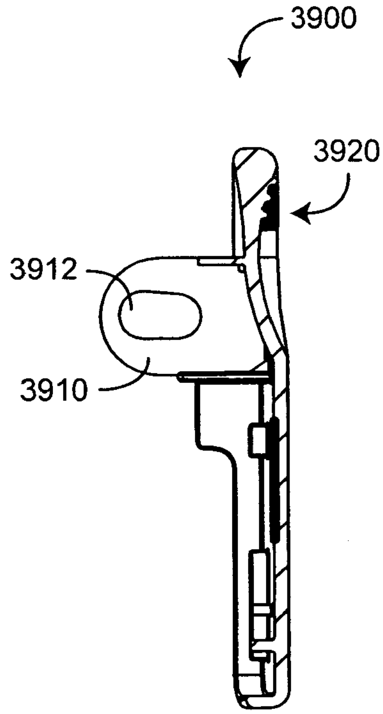

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FIG. 39D

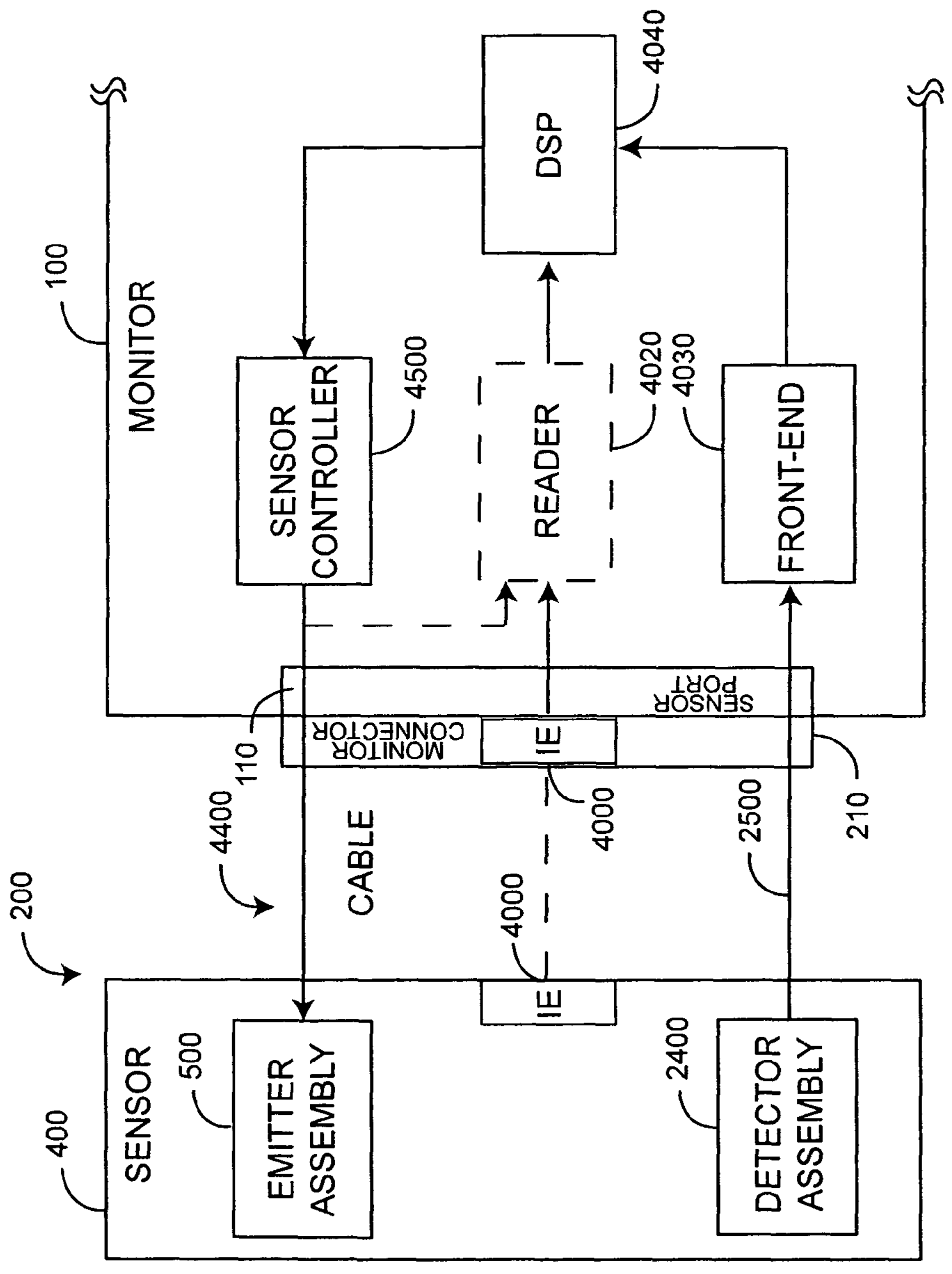
DSP
4040
100
MONITOR
SENSOR CONTROLLER
4500
READER
4020
4030
FRONT-END
MONITOR CONNECTOR
SENSOR PORT
IE
110
4400
CABLE
4000
2500
210
200
IE
SENSOR
400
500
EMITTER ASSEMBLY
2400
DETECTOR ASSEMBLY

FIG. 40

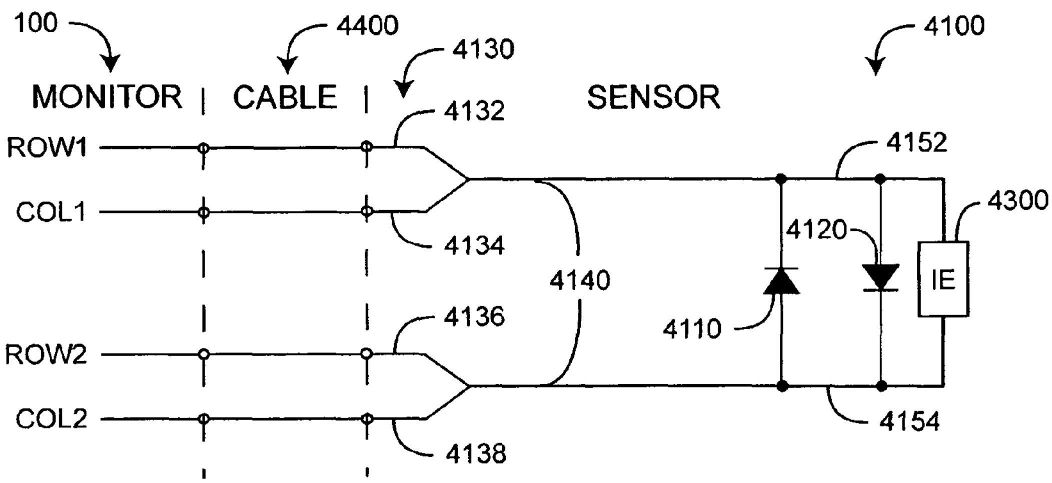

FIG. 41A

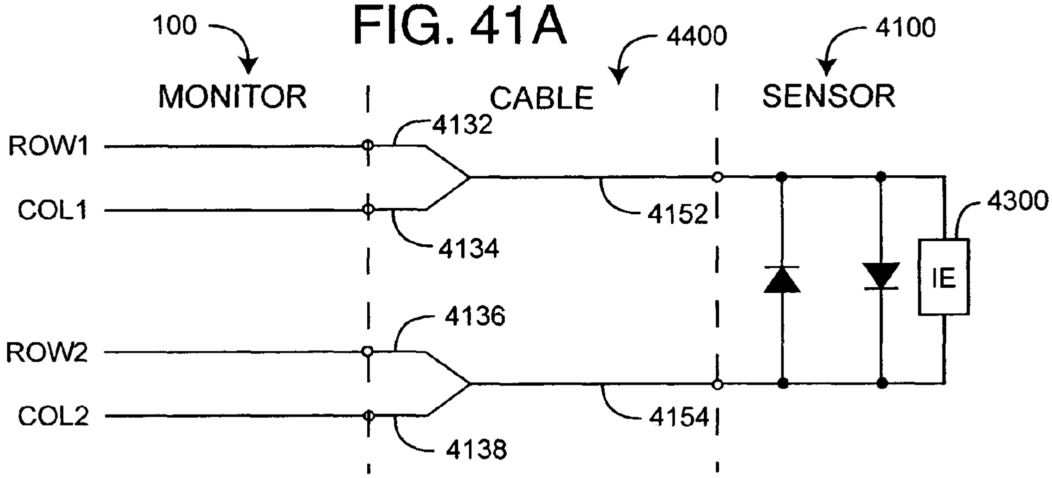

FIG. 41B

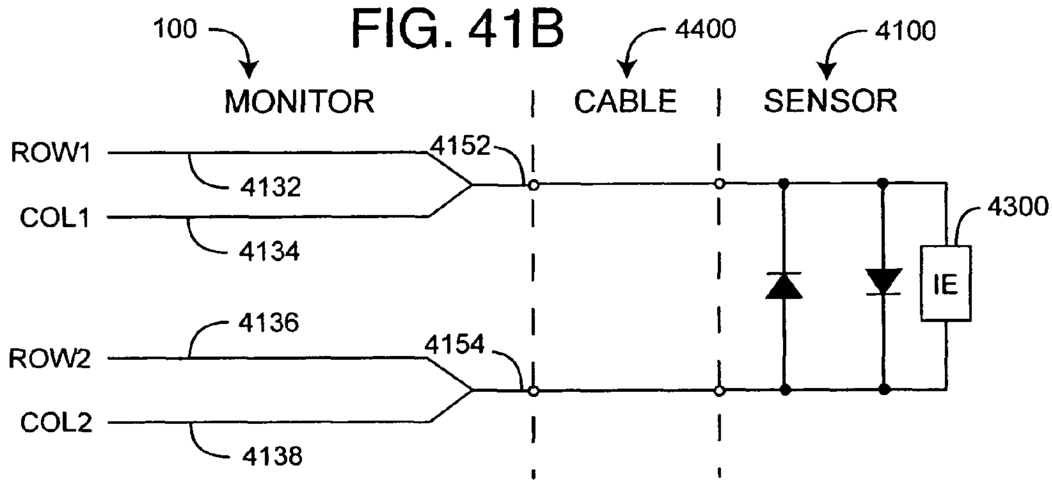

FIG. 41C

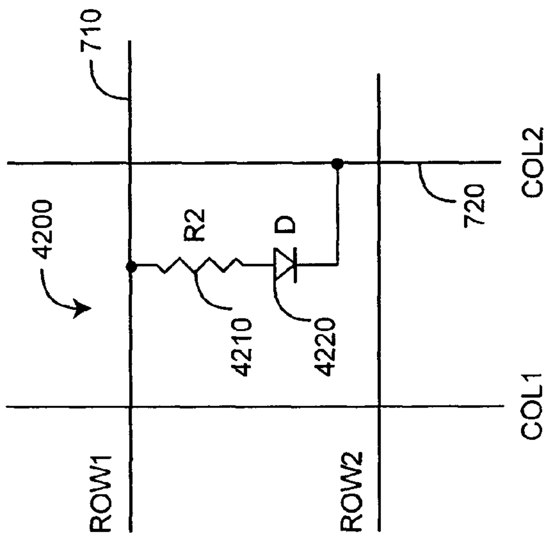

FIG. 42

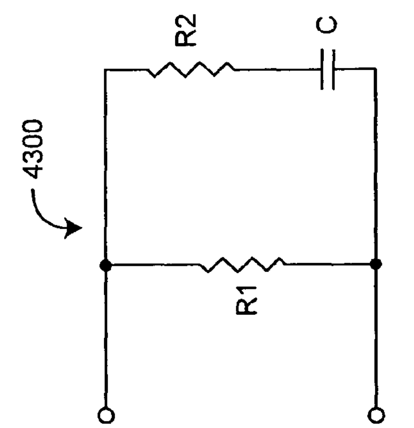

FIG. 43A

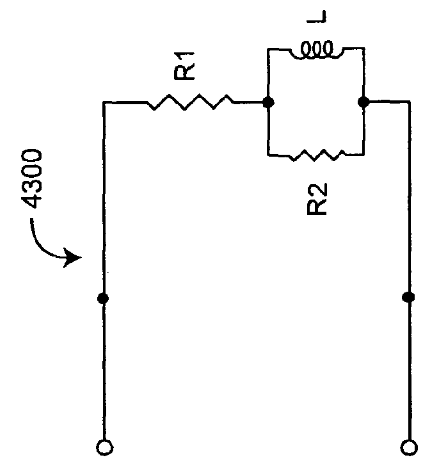

FIG. 43B

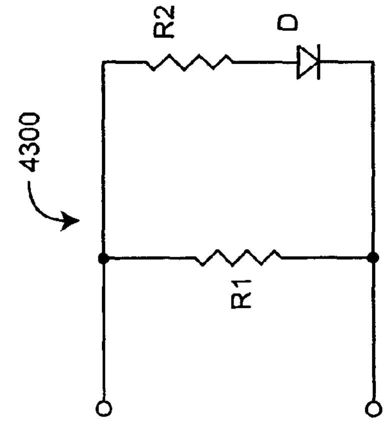

FIG. 43C

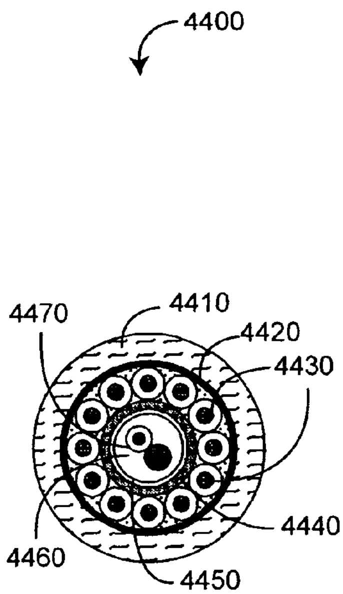

FIG. 44A

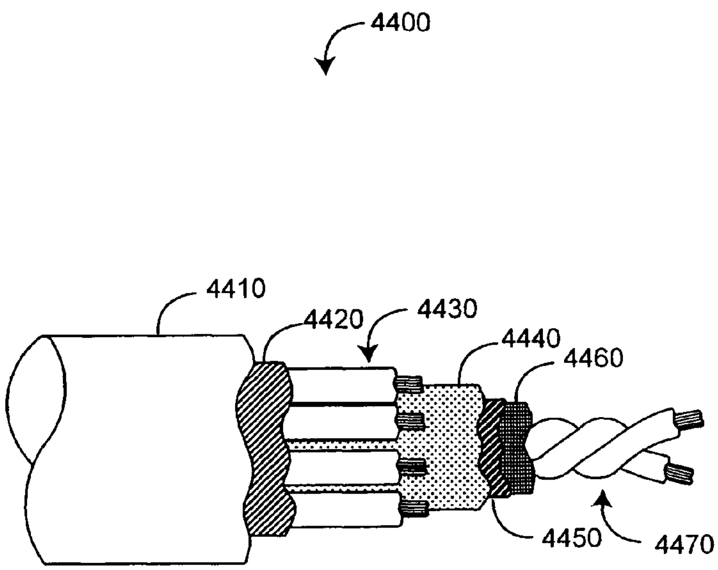

FIG. 44B

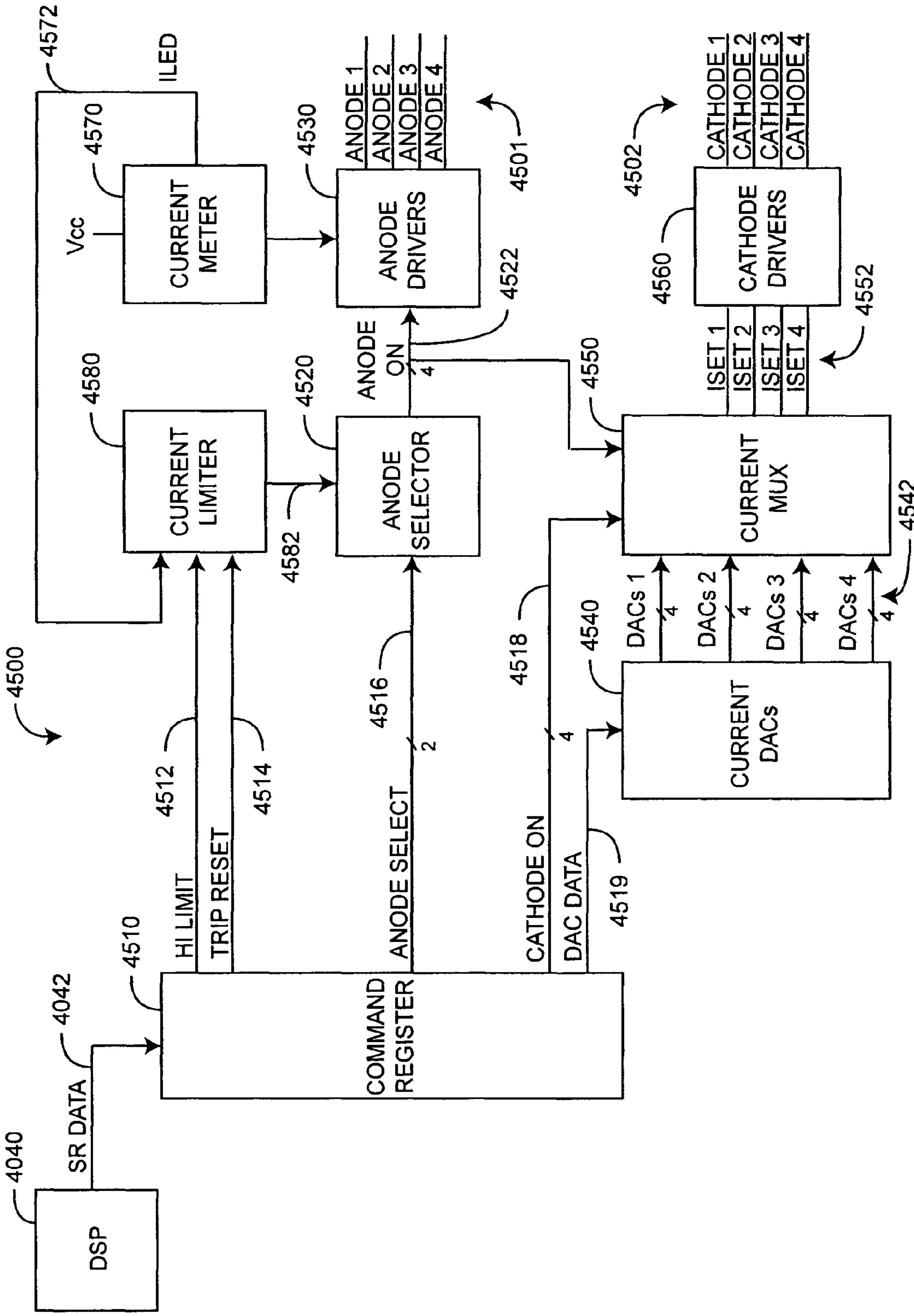
4500
DSP
4040
SR DATA
4042
COMMAND REGISTER
4510
HI LIMIT
TRIP RESET
4512
4514
ANODE SELECT
4516
2
CATHODE ON
DAC DATA
4518
4519
4
CURRENT LIMITER
4580
4582
CURRENT METER
4570
Vcc
ILED
4572
ANODE SELECTOR
4520
ANODE ON
4
4522
ANODE DRIVERS
4530
ANODE 1
ANODE 2
ANODE 3
ANODE 4
4501
CURRENT DACs
4540
DACs 1
DACs 2
DACs 3
DACs 4
CURRENT MUX
4550
4542
ISET 1
ISET 2
ISET 3
ISET 4
4552
CATHODE DRIVERS
4560
CATHODE 1
CATHODE 2
CATHODE 3
CATHODE 4
4502

FIG. 45

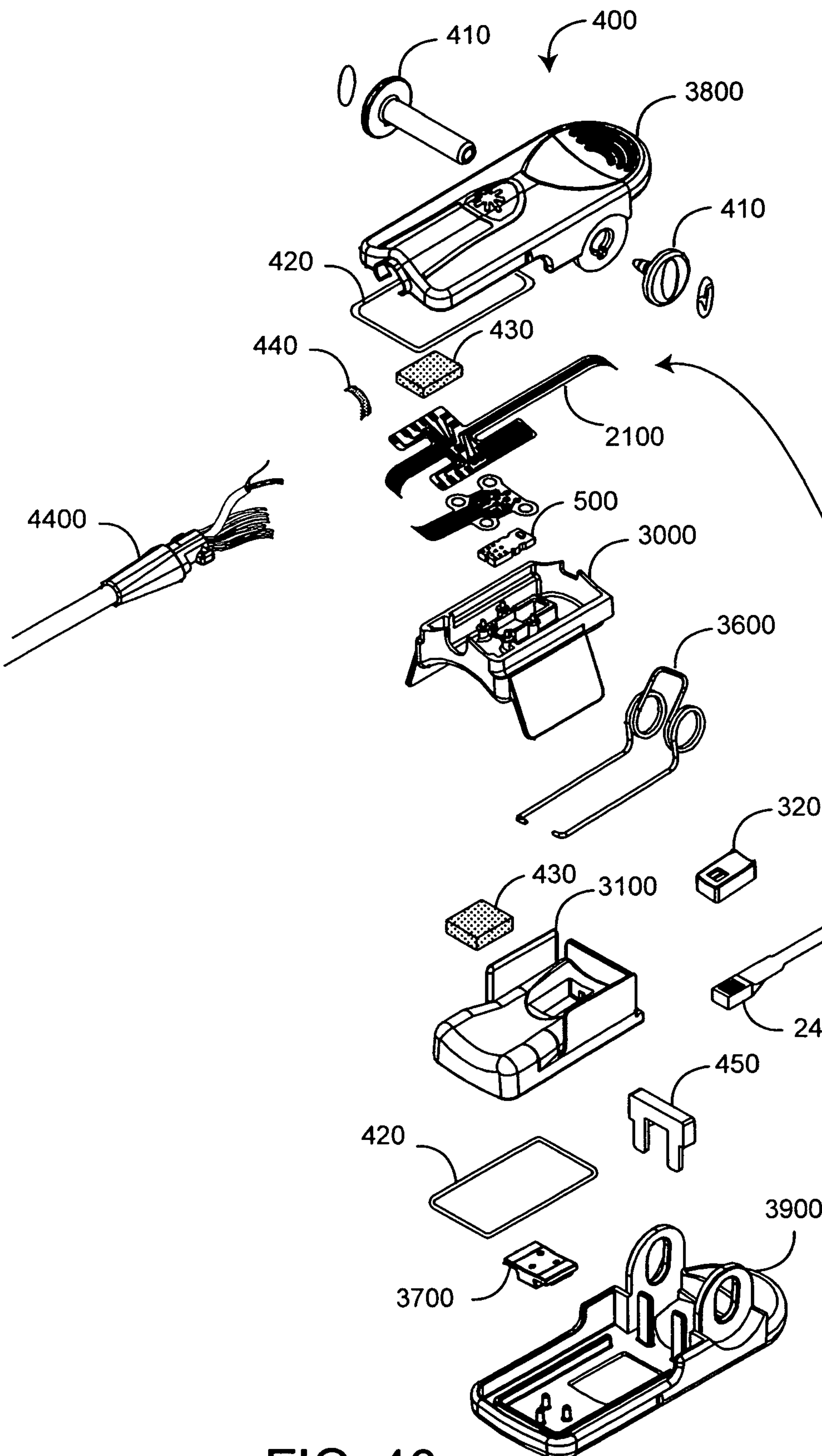
400
410
3800
410
420
430
440
2100
4400
500
3000
3600
2200
3200
430
3100
2400
450
420
3900
3700

FIG. 46

MULTIPLE WAVELENGTH SENSOR SUBSTRATE

PRIORITY CLAIM TO RELATED PROVISIONAL APPLICATIONS

The present application claims priority benefit under 35 U.S.C. §119(e) to U.S. Provisional Patent Application Ser. No. 60/657,596, filed Mar. 1, 2005, entitled "Multiple Wavelength Sensor," No. 60/657,281, filed Mar. 1, 2005, entitled "Physiological Parameter Confidence Measure," No. 60/657,268, filed Mar. 1, 2005, entitled "Configurable Physiological Measurement System," and No. 60/657,759, filed Mar. 1, 2005, entitled "Noninvasive Multi-Parameter Patient Monitor." The present application incorporates the foregoing disclosures herein by reference.

INCORPORATION BY REFERENCE OF COPENDING RELATED APPLICATIONS

The present application is related to the following copending U.S. utility applications:

	App. Sr. No.	Filing Date	Title	Atty Dock.
1	11/367,013	Mar. 1, 2006	Multiple Wavelength Sensor Emitters	MLR.002A
2	11/366,995	Mar. 1, 2006	Multiple Wavelength Sensor Equalization	MLR.003A
3	11/366,210	Mar. 1, 2006	Multiple Wavelength Sensor Substrate	MLR.004A
4	11/366,833	Mar. 1, 2006	Multiple Wavelength Sensor Interconnect	MLR.005A
5	11/366,997	Mar. 1, 2006	Multiple Wavelength Sensor Attachment	MLR.006A
6	11/367,034	Mar. 1, 2006	Multiple Wavelength Sensor Drivers	MLR.009A
7	11/367,036	Mar. 1, 2006	Physiological Parameter Confidence Measure	MLR.010A
8	11/367,033	Mar. 1, 2006	Configurable Physiological Measurement System	MLR.011A
9	11/367,014	Mar. 1, 2006	Noninvasive Multi-Parameter Patient Monitor	MLR.012A
10	11/366,208	Mar. 1, 2006	Noninvasive Multi-Parameter Patient Monitor	MLR.013A

The present application incorporates the foregoing disclosures herein by reference.

BACKGROUND OF THE INVENTION

Spectroscopy is a common technique for measuring the concentration of organic and some inorganic constituents of a solution. The theoretical basis of this technique is the Beer-Lambert law, which states that the concentration c_i of an absorbent in solution can be determined by the intensity of light transmitted through the solution, knowing the pathlength d_λ, the intensity of the incident light $I_{0,\lambda}$, and the extinction coefficient $\epsilon_{i,\lambda}$ at a particular wavelength λ. In generalized form, the Beer-Lambert law is expressed as:

$$I_\lambda = I_{0,\lambda} e^{-d_\lambda \cdot \mu_{a,\lambda}} \tag{1}$$

$$\mu_{a,\lambda} = \sum_{i=1}^{n} \varepsilon_{i,\lambda} \cdot c_i \tag{2}$$

where $\mu_{a,\lambda}$ is the bulk absorption coefficient and represents the probability of absorption per unit length. The minimum number of discrete wavelengths that are required to solve EQS. 1-2 are the number of significant absorbers that are present in the solution.

A practical application of this technique is pulse oximetry, which utilizes a noninvasive sensor to measure oxygen saturation (SpO_2) and pulse rate. In general, the sensor has light emitting diodes (LEDs) that transmit optical radiation of red and infrared wavelengths into a tissue site and a detector that responds to the intensity of the optical radiation after absorption (e.g., by transmission or transreflectance) by pulsatile arterial blood flowing within the tissue site. Based on this response, a processor determines measurements for SpO_2, pulse rate, and can output representative plethysmographic waveforms. Thus, "pulse oximetry" as used herein encompasses its broad ordinary meaning known to one of skill in the art, which includes at least those noninvasive procedures for measuring parameters of circulating blood through spectroscopy. Moreover, "plethysmograph" as used herein (commonly referred to as "photoplethysmograph"), encompasses its broad ordinary meaning known to one of skill in the art, which includes at least data representative of a change in the absorption of particular wavelengths of light as a function of the changes in body tissue resulting from pulsing blood. Pulse oximeters capable of reading through motion induced noise are available from Masimo Corporation ("Masimo") of Irvine, Calif. Moreover, portable and other oximeters capable of reading through motion induced noise are disclosed in at least U.S. Pat. Nos. 6,770,028, 6,658,276, 6,157,850, 6,002,952 5,769,785, and 5,758,644, which are owned by Masimo and are incorporated by reference herein. Such reading through motion oximeters have gained rapid acceptance in a wide variety of medical applications, including surgical wards, intensive care and neonatal units, general wards, home care, physical training, and virtually all types of monitoring scenarios.

SUMMARY OF THE INVENTION

There is a need to noninvasively measure multiple physiological parameters, other than, or in addition to, oxygen saturation and pulse rate. For example, hemoglobin species that are also significant under certain circumstances are carboxyhemoglobin and methemoglobin. Other blood parameters that may be measured to provide important clinical information are fractional oxygen saturation, total hemaglobin (Hbt), bilirubin and blood glucose, to name a few.

One aspect of a physiological sensor is emitters configured to transmit optical radiation having multiple wavelengths in response to corresponding drive currents. A thermal mass is disposed proximate the emitters so as to stabilize a bulk temperature for the emitters. A temperature sensor is thermally coupled to the thermal mass. The temperature sensor provides a temperature sensor output responsive to the bulk temperature so that the wavelengths are determinable as a function of the drive currents and the bulk temperature.

Another aspect of a physiological sensor capable of emitting light into tissue and producing an output signal usable to

determine one or more physiological parameters of a patient is a thermal mass. Light emitting sources are thermally coupled to the thermal mass. The sources have corresponding multiple operating wavelengths. A temperature sensor is thermally coupled to the thermal mass and is capable of determining a bulk temperature for the thermal mass, where the operating wavelengths are dependent on the bulk temperature. A detector is capable of detecting light emitted by the light emitting sources after tissue attenuation and is capable of outputting a signal usable to determine one or more physiological parameters of a patient based upon the operating wavelengths.

A further aspect of a physiological sensor adapted to determine a physiological parameter using light emitting sources with emission wavelengths affected by one or more dynamic operating parameters is to transmit optical radiation from the light emitting sources into body tissue. The optical radiation is detected after tissue attenuation. Multiple operating wavelengths of the light emitting sources are determined dependent on a bulk temperature of the light emitting sources. One or more physiological parameters of a patient are determined based upon the operating wavelengths.

An additional aspect of a physiological sensor is a sensor adapted to determine a physiological parameter using light emitting sources with emission wavelengths affected by one or more dynamic operating parameters. Optical radiation is transmitted from the light emitting sources into body tissue. The optical radiation is detected after tissue attenuation. An operating wavelength for each of the light emitting sources is indicated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a physiological measurement system utilizing a multiple wavelength sensor;

FIGS. **2**A-C are perspective views of multiple wavelength sensor embodiments;

FIG. **3** is a general block diagram of a multiple wavelength sensor and sensor controller;

FIG. **4** is an exploded perspective view of a multiple wavelength sensor embodiment;

FIG. **5** is a general block diagram of an emitter assembly;

FIG. **6** is a perspective view of an emitter assembly embodiment;

FIG. **7** is a general block diagram of an emitter array;

FIG. **8** is a schematic diagram of an emitter array embodiment;

FIG. **9** is a general block diagram of equalization;

FIGS. **10**A-D are block diagrams of various equalization embodiments;

FIGS. **11**A-C are perspective views of an emitter assembly incorporating various equalization embodiments;

FIG. **12** is a general block diagram of an emitter substrate;

FIGS. **13-14** are top and detailed side views of an emitter substrate embodiment;

FIGS. **15-16** are top and bottom component layout views of an emitter substrate embodiment;

FIG. **17** is a schematic diagram of an emitter substrate embodiment;

FIG. **18** is a plan view of an inner layer of an emitter substrate embodiment;

FIG. **19** is a general block diagram of an interconnect assembly in relationship to other sensor assemblies;

FIG. **20** is a block diagram of an interconnect assembly embodiment;

FIG. **21** is a partially-exploded perspective view of a flex circuit assembly embodiment of an interconnect assembly;

FIG. **22** is a top plan view of a flex circuit;

FIG. **23** is an exploded perspective view of an emitter portion of a flex circuit assembly;

FIG. **24** is an exploded perspective view of a detector assembly embodiment;

FIGS. **25-26** are block diagrams of adjacent detector and stacked detector embodiments;

FIG. **27** is a block diagram of a finger clip embodiment of an attachment assembly;

FIG. **28** is a general block diagram of a detector pad;

FIGS. **29**A-B are perspective views of detector pad embodiments;

FIGS. **30**A-H are perspective bottom, perspective top, bottom, back, top, side cross sectional, side, and front cross sectional views of an emitter pad embodiment;

FIGS. **31**A-H are perspective bottom, perspective top, top, back, bottom, side cross sectional, side, and front cross sectional views of a detector pad embodiment;

FIGS. **32**A-H are perspective bottom, perspective top, top, back, bottom, side cross sectional, side, and front cross sectional views of a shoe box;

FIGS. **33**A-H are perspective bottom, perspective top, top, back, bottom, side cross sectional, side, and front cross sectional views of a slim-finger emitter pad embodiment;

FIGS. **34**A-H are perspective bottom, perspective top, top, back, bottom, side cross sectional, side, and front cross sectional views of a slim-finger detector pad embodiment;

FIGS. **35**A-B are plan and cross sectional views, respectively, of a spring assembly embodiment;

FIGS. **36**A-C are top, perspective and side views of a finger clip spring;

FIGS. **37**A-D are top, back, bottom, and side views of a spring plate;

FIGS. **38**A-D are front cross sectional, bottom, front and side cross sectional views of an emitter-pad shell;

FIGS. **39**A-D are back, top, front and side cross sectional views of a detector-pad shell;

FIG. **40** is a general block diagram of a monitor and a sensor;

FIGS. **41**A-C are schematic diagrams of grid drive embodiments for a sensor having back-to-back diodes and an information element;

FIGS. **42** is a schematic diagrams of a grid drive embodiment for an information element; FIGS. **43**A-C are schematic diagrams for grid drive readable information elements;

FIGS. **44**A-B are cross sectional and side cut away views of a sensor cable;

FIG. **45** is a block diagram of a sensor controller embodiment; and

FIG. **46** is a detailed exploded perspective view of a multiple wavelength sensor embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Overview

In this application, reference is made to many blood parameters. Some references that have common shorthand designations are referenced through such shorthand designations. For example, as used herein, HbCO designates carboxyhemoglobin, HbMet designates methemoglobin, and Hbt designates total hemoglobin. Other shorthand designations such as COHb, MetHb, and tHb are also common in the art for these same constituents. These constituents are generally reported in terms of a percentage, often referred to as saturation, relative concentration or fractional saturation. Total hemoglobin

is generally reported as a concentration in g/dL. The use of the particular shorthand designators presented in this application does not restrict the term to any particular manner in which the designated constituent is reported.

FIG. **1** illustrates a physiological measurement system **10** having a monitor **100** and a multiple wavelength sensor assembly **200** with enhanced measurement capabilities as compared with conventional pulse oximetry. The physiological measurement system **10** allows the monitoring of a person, including a patient. In particular, the multiple wavelength sensor assembly **200** allows the measurement of blood constituent and related parameters in addition to oxygen saturation and pulse rate. Alternatively, the multiple wavelength sensor assembly **200** allows the measurement of oxygen saturation and pulse rate with increased accuracy or robustness as compared with conventional pulse oximetry.

In one embodiment, the sensor assembly **200** is configured to plug into a monitor sensor port **110**. Monitor keys **160** provide control over operating modes and alarms, to name a few. A display **170** provides readouts of measured parameters, such as oxygen saturation, pulse rate, HbCO and HbMet to name a few.

FIGS. **2**A illustrates a multiple wavelength sensor assembly **200** having a sensor **400** adapted to attach to a tissue site, a sensor cable **4400** and a monitor connector **210**. In one embodiment, the sensor **400** is incorporated into a reusable finger clip adapted to removably attach to, and transmit light through, a fingertip. The sensor cable **4400** and monitor connector **210** are integral to the sensor **400**, as shown. In alternative embodiments, the sensor **400** may be configured separately from the cable **4400** and connector **210**.

FIGS. **2**B-C illustrate alternative sensor embodiments, including a sensor **401** (FIG. **2**B) partially disposable and partially reusable (resposable) and utilizing an adhesive attachment mechanism. Also shown is a sensor **402** (FIG. **2**C) being disposable and utilizing an adhesive attachment mechanism. In other embodiments, a sensor may be configured to attach to various tissue sites other than a finger, such as a foot or an ear. Also a sensor may be configured as a reflectance or transflectance device that attaches to a forehead or other tissue surface.

FIG. **3** illustrates a sensor assembly **400** having an emitter assembly **500**, a detector assembly **2400**, an interconnect assembly **1900** and an attachment assembly **2700**. The emitter assembly **500** responds to drive signals received from a sensor controller **4500** in the monitor **100** via the cable **4400** so as to transmit optical radiation having a plurality of wavelengths into a tissue site. The detector assembly **2400** provides a sensor signal to the monitor **100** via the cable **4400** in response to optical radiation received after attenuation by the tissue site. The interconnect assembly **1900** provides electrical communication between the cable **4400** and both the emitter assembly **500** and the detector assembly **2400**. The attachment assembly **2700** attaches the emitter assembly **500** and detector assembly **2400** to a tissue site, as described above. The emitter assembly **500** is described in further detail with respect to FIG. **5**, below. The interconnect assembly **1900** is described in further detail with respect to FIG. **19**, below. The detector assembly **2400** is described in further detail with respect to FIG. **24**, below. The attachment assembly **2700** is described in further detail with respect to FIG. **27**, below.

FIG. **4** illustrates a sensor **400** embodiment that removably attaches to a fingertip. The sensor **400** houses a multiple wavelength emitter assembly **500** and corresponding detector assembly **2400**. A flex circuit assembly **1900** mounts the emitter and detector assemblies **500**, **2400** and interconnects them to a multi-wire sensor cable **4400**. Advantageously, the sensor **400** is configured in several respects for both wearer comfort and parameter measurement performance. The flex circuit assembly **1900** is configured to mechanically decouple the cable **4400** wires from the emitter and detector assemblies **500**, **2400** to reduce pad stiffness and wearer discomfort. The pads **3000**, **3100** are mechanically decoupled from shells **3800**, **3900** to increase flexibility and wearer comfort. A spring **3600** is configured in hinged shells **3800**, **3900** so that the pivot point of the finger clip is well behind the fingertip, improving finger attachment and more evenly distributing the clip pressure along the finger.

As shown in FIG. **4**, the detector pad **3100** is structured to properly position a fingertip in relationship to the detector assembly **2400**. The pads have flaps that block ambient light. The detector assembly **2400** is housed in an enclosure so as to reduce light piping from the emitter assembly to the detector assembly without passing through fingertip tissue. These and other features are described in detail below. Specifically, emitter assembly embodiments are described with respect to FIGS. **5-18**. Interconnect assembly embodiments, including the flexible circuit assembly **1900**, are described with respect to FIGS. **19-23**. Detector assembly embodiments are described with respect to FIGS. **24-26**. Attachment assembly embodiments are described with respect to FIGS. **27-39**.

Emitter Assembly

FIG. **5** illustrates an emitter assembly **500** having an emitter array **700**, a substrate **1200** and equalization **900**. The emitter array **700** has multiple light emitting sources, each activated by addressing at least one row and at least one column of an electrical grid. The light emitting sources are capable of transmitting optical radiation having multiple wavelengths. The equalization **900** accounts for differences in tissue attenuation of the optical radiation across the multiple wavelengths so as to at least reduce wavelength-dependent variations in detected intensity. The substrate **1200** provides a physical mount for the emitter array and emitter-related equalization and a connection between the emitter array and the interconnection assembly. Advantageously, the substrate **1200** also provides a bulk temperature measurement so as to calculate the operating wavelengths for the light emitting sources. The emitter array **700** is described in further detail with respect to FIG. **7**, below. Equalization is described in further detail with respect to FIG. **9**, below. The substrate **1200** is described in further detail with respect to FIG. **12**, below.

FIG. **6** illustrates an emitter assembly **500** embodiment having an emitter array **700**, an encapsulant **600**, an optical filter **1100** and a substrate **1200**. Various aspects of the emitter assembly **500** are described with respect to FIGS. **7-18**, below. The emitter array **700** emits optical radiation having multiple wavelengths of predetermined nominal values, advantageously allowing multiple parameter measurements. In particular, the emitter array **700** has multiple light emitting diodes (LEDs) **710** that are physically arranged and electrically connected in an electrical grid to facilitate drive control, equalization, and minimization of optical pathlength differences at particular wavelengths. The optical filter **1100** is advantageously configured to provide intensity equalization across a specific LED subset. The substrate **1200** is configured to provide a bulk temperature of the emitter array **700** so as to better determine LED operating wavelengths.

Emitter Array

FIG. **7** illustrates an emitter array **700** having multiple light emitters (LE) **710** capable of emitting light **702** having multiple wavelengths into a tissue site **1**. Row drivers **4530** and

column drivers **4560** are electrically connected to the light emitters **710** and activate one or more light emitters **710** by addressing at least one row **720** and at least one column **740** of an electrical grid. In one embodiment, the light emitters **710** each include a first contact **712** and a second contact **714**. The first contact **712** of a first subset **730** of light emitters is in communication with a first conductor **720** of the electrical grid. The second contact **714** of a second subset **750** of light emitters is in communication with a second conductor **740**. Each subset comprises at least two light emitters, and at least one of the light emitters of the first and second subsets **730**, **750** are not in common. A detector **2400** is capable of detecting the emitted light **702** and outputting a sensor signal **2500** responsive to the emitted light **702** after attenuation by the tissue site **1**. As such, the sensor signal **2500** is indicative of at least one physiological parameter corresponding to the tissue site **1**, as described above.

FIG. **8** illustrates an emitter array **700** having LEDs **801** connected within an electrical grid of n rows and m columns totaling n+m drive lines **4501**, **4502**, where n and m integers greater than one. The electrical grid advantageously minimizes the number of drive lines required to activate the LEDs **801** while preserving flexibility to selectively activate individual LEDs **801** in any sequence and multiple LEDs **801** simultaneously. The electrical grid also facilitates setting LED currents so as to control intensity at each wavelength, determining operating wavelengths and monitoring total grid current so as to limit power dissipation. The emitter array **700** is also physically configured in rows **810**. This physical organization facilitates clustering LEDs **801** according to wavelength so as to minimize pathlength variations and facilitates equalization of LED intensities.

As shown in FIG. **8**, one embodiment of an emitter array **700** comprises up to sixteen LEDs **801** configured in an electrical grid of four rows **810** and four columns **820**. Each of the four row drive lines **4501** provide a common anode connection to four LEDs **801**, and each of the four column drive lines **4502** provide a common cathode connection to four LEDs **801**. Thus, the sixteen LEDs **801** are advantageously driven with only eight wires, including four anode drive lines **812** and four cathode drive lines **822**. This compares favorably to conventional common anode or cathode LED configurations, which require more drive lines. In a particular embodiment, the emitter array **700** is partially populated with eight LEDs having nominal wavelengths as shown in TABLE 1. Further, LEDs having wavelengths in the range of 610-630 nm are grouped together in the same row. The emitter array **700** is adapted to a physiological measurement system **10** (FIG. **1**) for measuring H_bCO and/or METHb in addition to S_pO_2 and pulse rate.

TABLE 1

Nominal LED Wavelengths			
LED	λ	Row	Col
D1	630	1	1
D2	620	1	2
D3	610	1	3
D4		1	4
D5	700	2	1
D6	730	2	2
D7	660	2	3
D8	805	2	4
D9		3	1
D10		3	2
D11		3	3
D12	905	3	4

TABLE 1-continued

Nominal LED Wavelengths			
LED	λ	Row	Col
D13		4	1
D14		4	2
D15		4	3
D16		4	4

Also shown in FIG. **8**, row drivers **4530** and column drivers **4560** located in the monitor **100** selectively activate the LEDs **801**. In particular, row and column drivers **4530**, **4560** function together as switches to Vcc and current sinks, respectively, to activate LEDs and as switches to ground and Vcc, respectively, to deactivate LEDs. This push-pull drive configuration advantageously prevents parasitic current flow in deactivated LEDs. In a particular embodiment, only one row drive line **4501** is switched to Vcc at a time. One to four column drive lines **4502**, however, can be simultaneously switched to a current sink so as to simultaneously activate multiple LEDs within a particular row. Activation of two or more LEDs of the same wavelength facilitates intensity equalization, as described with respect to FIGS. **9-11**, below. LED drivers are described in further detail with respect to FIG. **45**, below.

Although an emitter assembly is described above with respect to an array of light emitters each configured to transmit optical radiation centered around a nominal wavelength, in another embodiment, an emitter assembly advantageously utilizes one or more tunable broadband light sources, including the use of filters to select the wavelength, so as to minimize wavelength-dependent pathlength differences from emitter to detector. In yet another emitter assembly embodiment, optical radiation from multiple emitters each configured to transmit optical radiation centered around a nominal wavelength is funneled to a tissue site point so as to minimize wavelength-dependent pathlength differences. This funneling may be accomplish with fiberoptics or mirrors, for example. In further embodiments, the LEDs **801** can be configured with alternative orientations with correspondingly different drivers among various other configurations of LEDs, drivers and interconnecting conductors.

Equalization

FIG. **9** illustrate a physiological parameter measurement system **10** having a controller **4500**, an emitter assembly **500**, a detector assembly **2400** and a front-end **4030**. The emitter assembly **500** is configured to transmit optical radiation having multiple wavelengths into the tissue site **1**. The detector assembly **2400** is configured to generate a sensor signal **2500** responsive to the optical radiation after tissue attenuation. The front-end **4030** conditions the sensor signal **2500** prior to analog-to-digital conversion (ADC).

FIG. **9** also generally illustrates equalization **900** in a physiological measurement system **10** operating on a tissue site **1**. Equalization encompasses features incorporated into the system **10** in order to provide a sensor signal **2500** that falls well within the dynamic range of the ADC across the entire spectrum of emitter wavelengths. In particular, equalization compensates for the imbalance in tissue light absorption due to Hb and HbO_2 **910**. Specifically, these blood constituents attenuate red wavelengths greater than IR wavelengths. Ideally, equalization **900** balances this unequal attenuation. Equalization **900** can be introduced anywhere in the system **10** from the controller **4500** to front-end **4000** and

can include compensatory attenuation versus wavelength, as shown, or compensatory amplification versus or both.

Equalization can be achieved to a limited extent by adjusting drive currents from the controller **4500** and front-end **4030** amplification accordingly to wavelength so as to compensate for tissue absorption characteristics. Signal demodulation constraints, however, limit the magnitude of these adjustments. Advantageously, equalization **900** is also provided along the optical path from emitters **500** to detector **2400**. Equalization embodiments are described in further detail with respect to FIGS. **10-11**, below.

FIGS. **10**A-D illustrate various equalization embodiments having an emitter array **700** adapted to transmit optical radiation into a tissue site **1** and a detector assembly **2400** adapted to generate a sensor signal **2500** responsive to the optical radiation after tissue attenuation. FIG. **10**A illustrates an optical filter **1100** that attenuates at least a portion of the optical radiation before it is transmitted into a tissue site **1**. In particular, the optical filter **1100** attenuates at least a portion of the IR wavelength spectrum of the optical radiation so as to approximate an equalization curve **900** (FIG. **9**). FIG. **10**B illustrates an optical filter **1100** that attenuates at least a portion of the optical radiation after it is attenuated by a tissue site **1**, where the optical filter **1100** approximates an equalization curve **900** (FIG. **9**).

FIG. **10**C illustrates an emitter array **700** where at least a portion of the emitter array generates one or more wavelengths from multiple light emitters **710** of the same wavelength. In particular, the same-wavelength light emitters **710** boost at least a portion of the red wavelength spectrum so as to approximately equalize the attenuation curves **910** (FIG. **9**). FIG. **10**D illustrates a detector assembly **2400** having multiple detectors **2610**, **2620** selected so as to equalize the attenuation curves **910** (FIG. **9**). To a limited extent, optical equalization can also be achieved by selection of particular emitter array **700** and detector **2400** components, e.g. LEDs having higher output intensities or detectors having higher sensitivities at red wavelengths. Although equalization embodiments are described above with respect to red and IR wavelengths, these equalization embodiments can be applied to equalize tissue characteristics across any portion of the optical spectrum.

FIGS. **11**A-C illustrates an optical filter **1100** for an emitter assembly **500** that advantageously provides optical equalization, as described above. LEDs within the emitter array **700** may be grouped according to output intensity or wavelength or both. Such a grouping facilitates equalization of LED intensity across the array. In particular, relatively low tissue absorption and/or relatively high output intensity LEDs can be grouped together under a relatively high attenuation optical filter. Likewise, relatively low tissue absorption and/or relatively low output intensity LEDs can be grouped together without an optical filter or under a relatively low or negligible attenuation optical filter. Further, high tissue absorption and/or low intensity LEDs can be grouped within the same row with one or more LEDs of the same wavelength being simultaneously activated, as described with respect to FIG. **10**C, above. In general, there can be any number of LED groups and any number of LEDs within a group. There can also be any number of optical filters corresponding to the groups having a range of attenuation, including no optical filter and/or a "clear" filter having negligible attenuation.

As shown in FIGS. **11**A-C, a filtering media may be advantageously added to an encapsulant that functions both as a cover to protect LEDs and bonding wires and as an optical filter **1100**. In one embodiment, a filtering media **1100** encapsulates a select group of LEDs and a clear media **600** (FIG. **6**) encapsulates the entire array **700** and the filtering media **1000** (FIG. **6**). In a particular embodiment, corresponding to TABLE 1, above, five LEDs nominally emitting at 660-905 nm are encapsulated with both a filtering media **1100** and an overlying clear media **600** (FIG. **6**), i.e. attenuated. In a particular embodiment, the filtering media **1100** is a 40:1 mixture of a clear encapsulant (EPO-TEK OG147-7) and an opaque encapsulate (EPO-TEK OG147) both available from Epoxy Technology, Inc., Billerica, Mass. Three LEDs nominally emitting at 610-630 nm are only encapsulated with the clear media **600** (FIG. **6**), i.e. unattenuated. In alternative embodiments, individual LEDs may be singly or multiply encapsulated according to tissue absorption and/or output intensity. In other alternative embodiments, filtering media may be separately attachable optical filters or a combination of encapsulants and separately attachable optical filters. In a particular embodiment, the emitter assembly **500** has one or more notches along each side proximate the component end **1305** (FIG. **13**) for retaining one or more clip-on optical filters.

Substrate

FIG. **12** illustrates light emitters **710** configured to transmit optical radiation **1201** having multiple wavelengths in response to corresponding drive currents **1210**. A thermal mass **1220** is disposed proximate the emitters **710** so as to stabilize a bulk temperature **1202** for the emitters. A temperature sensor **1230** is thermally coupled to the thermal mass **1220**, wherein the temperature sensor **1230** provides a temperature sensor output **1232** responsive to the bulk temperature **1202** so that the wavelengths are determinable as a function of the drive currents **1210** and the bulk temperature **1202**.

In one embodiment, an operating wavelength λ_a of each light emitter **710** is determined according to EQ. 3

$$\lambda_{a=f}(T_b, I_{drive}, \Sigma I_{drive}) \tag{3}$$

where T_b is the bulk temperature, I_{drive} is the drive current for a particular light emitter, as determined by the sensor controller **4500** (FIG. **45**), described below, and ΣI_{drive} is the total drive current for all light emitters. In another embodiment, temperature sensors are configured to measure the temperature of each light emitter **710** and an operating wavelength λ_a of each light emitter **710** is determined according to EQ. 4

$$\lambda_a = f(T_a, I_{drive}, \Sigma I_{drive}) \tag{4}$$

where T_a is the temperature of a particular light emitter, I_{drive} is the drive current for that light emitter and ΣI_{drive} is the total drive current for all light emitters.

In yet another embodiment, an operating wavelength for each light emitter is determined by measuring the junction voltage for each light emitter **710**. In a further embodiment, the temperature of each light emitter **710** is controlled, such as by one or more Peltier cells coupled to each light emitter **710**, and an operating wavelength for each light emitter **710** is determined as a function of the resulting controlled temperature or temperatures. In other embodiments, the operating wavelength for each light emitter **710** is determined directly, for example by attaching a charge coupled device (CCD) to each light emitter or by attaching a fiberoptic to each light emitter and coupling the fiberoptics to a wavelength measuring device, to name a few.

FIGS. **13-18** illustrate one embodiment of a substrate **1200** configured to provide thermal conductivity between an emitter array **700** (FIG. **8**) and a thermistor **1540** (FIG. **16**). In this manner, the resistance of the thermistor **1540** (FIG. **16**) can be measured in order to determine the bulk temperature of LEDs **801** (FIG. **8**) mounted on the substrate **1200**. The substrate

1200 is also configured with a relatively significant thermal mass, which stabilizes and normalizes the bulk temperature so that the thermistor measurement of bulk temperature is meaningful.

FIGS. **13-14** illustrate a substrate **1200** having a component side **1301**, a solder side **1302**, a component end **1305** and a connector end **1306**. Alignment notches **1310** are disposed between the ends **1305**, **1306**. The substrate **1200** further has a component layer **1401**, inner layers **1402-1405** and a solder layer **1406**. The inner layers **1402-1405**, e.g. inner layer **1402** (FIG. **18**), have substantial metallized areas **1411** that provide a thermal mass **1220** (FIG. **12**) to stabilize a bulk temperature for the emitter array **700** (FIG. **12**). The metallized areas **1411** also function to interconnect component pads **1510** and wire bond pads **1520** (FIG. **15**) to the connector **1530**.

FIGS. **15-16** illustrate a substrate **1200** having component pads **1510** and wire bond pads **1520** at a component end **1305**. The component pads **1510** mount and electrically connect a first side (anode or cathode) of the LEDs **801** (FIG. **8**) to the substrate **1200**. Wire bond pads **1520** electrically connect a second side (cathode or anode) of the LEDs **801** (FIG. **8**) to the substrate **1200**. The connector end **1306** has a connector **1530** with connector pads **1532**, **1534** that mount and electrically connect the emitter assembly **500** (FIG. **23**), including the substrate **1200**, to the flex circuit **2200** (FIG. **22**). Substrate layers **1401-1406** (FIG. **14**) have traces that electrically connect the component pads **1510** and wire bond pads **1520** to the connector **1532-1534**. A thermistor **1540** is mounted to thermistor pads **1550** at the component end **1305**, which are also electrically connected with traces to the connector **1530**. Plated thru holes electrically connect the connector pads **1532**, **1534** on the component and solder sides **1301**, **1302**, respectively.

FIG. **17** illustrates the electrical layout of a substrate **1200**. A portion of the LEDs **801**, including D**1**-D**4** and D**13**-D**16** have cathodes physically and electrically connected to component pads **1510** (FIG. **15**) and corresponding anodes wire bonded to wire bond pads **1520**. Another portion of the LEDs **801**, including D**5**-D**8** and D**9**-D**12**, have anodes physically and electrically connected to component pads **1510** (FIG. **15**) and corresponding cathodes wire bonded to wire bond pads **1520**. The connector **1530** has row pinouts J**21**-J**24**, column pinouts J**31**-J**34** and thermistor pinouts J**40**-J**41** for the LEDs **801** and thermistor **1540**.

Interconnect Assembly

FIG. **19** illustrates an interconnect assembly **1900** that mounts the emitter assembly **500** and detector assembly **2400**, connects to the sensor cable **4400** and provides electrical communications between the cable and each of the emitter assembly **500** and detector assembly **2400**. In one embodiment, the interconnect assembly **1900** is incorporated with the attachment assembly **2700**, which holds the emitter and detector assemblies to a tissue site. An interconnect assembly embodiment utilizing a flexible (flex) circuit is described with respect to FIGS. **20-24**, below.

FIG. **20** illustrates an interconnect assembly **1900** embodiment having a circuit substrate **2200**, an emitter mount **2210**, a detector mount **2220** and a cable connector **2230**. The emitter mount **2210**, detector mount **2220** and cable connector **2230** are disposed on the circuit substrate **2200**. The emitter mount **2210** is adapted to mount an emitter assembly **500** having multiple emitters. The detector mount **2220** is adapted to mount a detector assembly **2400** having a detector. The cable connector **2230** is adapted to attach a sensor cable **4400**. A first plurality of conductors **2040** disposed on the circuit substrate **2200** electrically interconnects the emitter mount **2210** and the cable connector **2230**. A second plurality of conductors **2050** disposed on the circuit substrate **2200** electrically interconnects the detector mount **2220** and the cable connector **2230**. A decoupling **2060** disposed proximate the cable connector **2230** substantially mechanically isolates the cable connector **2230** from both the emitter mount **2210** and the detector mount **2220** so that sensor cable stiffness is not translated to the emitter assembly **500** or the detector assembly **2400**. A shield **2070** is adapted to fold over and shield one or more wires or pairs of wires of the sensor cable **4400**.

FIG. **21** illustrates a flex circuit assembly **1900** having a flex circuit **2200**, an emitter assembly **500** and a detector assembly **2400**, which is configured to terminate the sensor end of a sensor cable **4400**. The flex circuit assembly **1900** advantageously provides a structure that electrically connects yet mechanically isolates the sensor cable **4400**, the emitter assembly **500** and the detector assembly **2400**. As a result, the mechanical stiffness of the sensor cable **4400** is not translated to the sensor pads **3000**, **3100** (FIGS. **30-31**), allowing a comfortable finger attachment for the sensor **200** (FIG. **1**). In particular, the emitter assembly **500** and detector assembly **2400** are mounted to opposite ends **2201**, **2202** (FIG. **22**) of an elongated flex circuit **2200**. The sensor cable **4400** is mounted to a cable connector **2230** extending from a middle portion of the flex circuit **2200**. Detector wires **4470** are shielded at the flex circuit junction by a fold-over conductive ink flap **2240**, which is connected to a cable inner shield **4450**. The flex circuit **2200** is described in further detail with respect to FIG. **22**. The emitter portion of the flex circuit assembly **1900** is described in further detail with respect to FIG. **23**. The detector assembly **2400** is described with respect to FIG. **24**. The sensor cable **4400** is described with respect to FIGS. **44**A-B, below.

FIG. **22** illustrates a sensor flex circuit **2200** having an emitter end **2201**, a detector end **2202**, an elongated interconnect **2204**, **2206** between the ends **2201**, **2202** and a cable connector **2230** extending from the interconnect **2204**, **2206**. The emitter end **2201** forms a "head" having emitter solder pads **2210** for attaching the emitter assembly **500** (FIG. **6**) and mounting ears **2214** for attaching to the emitter pad **3000** (FIG. **30**B), as described below. The detector end **2202** has detector solder pads for attaching the detector **2410** (FIG. **24**). The interconnect **2204** between the emitter end **2201** and the cable connector **2230** forms a "neck," and the interconnect **2206** between the detector end **2202** and the cable connector **2230** forms a "tail." The cable connector **2230** forms "wings" that extend from the interconnect **2204**, **2206** between the neck **2204** and tail **2206**. A conductive ink flap **2240** connects to the cable inner shield **4450** (FIGS. **44**A-B) and folds over to shield the detector wires **4470** (FIGS. **44**A-B) soldered to the detector wire pads **2236**. The outer wire pads **2238** connect to the remaining cable wires **4430** (FIGS. **44**A-B). The flex circuit **2200** has top coverlay, top ink, inner coverlay, trace, trace base, bottom ink and bottom coverlay layers.

The flex circuit **2200** advantageously provides a connection between a multiple wire sensor cable **4400** (FIGS. **44**A-B), a multiple wavelength emitter assembly **500** (FIG. **6**) and a detector assembly **2400** (FIG. **24**) without rendering the emitter and detector assemblies unwieldy and stiff. In particular, the wings **2230** provide a relatively large solder pad area **2232** that is narrowed at the neck **2204** and tail **2206** to mechanically isolate the cable **4400** (FIGS. **44**A-B) from the remainder of the flex circuit **2200**. Further, the neck **2206** is folded (see FIG. **4**) for installation in the emitter pad **3000** (FIGS. **30**A-H) and acts as a flexible spring to further mechanically isolate the cable **4400** (FIGS. **44**A-B) from the emitter assembly **500** (FIG. **4**). The tail **2206** provides an

integrated connectivity path between the detector assembly **2400** (FIG. **24**) mounted in the detector pad **3100** (FIGS. **31**A-H) and the cable connector **2230** mounted in the opposite emitter pad **3000** (FIGS. **30**A-H).

FIG. **23** illustrates the emitter portion of the flex circuit assembly **1900** (FIG. **21**) having the emitter assembly **500**. The emitter assembly connector **1530** is attached to the emitter end **2210** of the flex circuit **2200** (FIG. **22**). In particular, reflow solder **2330** connects thru hole pads **1532**, **1534** of the emitter assembly **500** to corresponding emitter pads **2310** of the flex circuit **2200** (FIG. **22**).

FIG. **24** illustrates a detector assembly **2400** including a detector **2410**, solder pads **2420**, copper mesh tape **2430**, an EMI shield **2440** and foil **2450**. The detector **2410** is soldered **2460** chip side down to detector solder pads **2420** of the flex circuit **2200**. The detector solder joint and detector ground pads **2420** are wrapped with the Kapton tape **2470**. EMI shield tabs **2442** are folded onto the detector pads **2420** and soldered. The EMI shield walls are folded around the detector **2410** and the remaining tabs **2442** are soldered to the back of the EMI shield **2440**. The copper mesh tape **2430** is cut to size and the shielded detector and flex circuit solder joint are wrapped with the copper mesh tape **2430**. The foil **2450** is cut to size with a predetermined aperture **2452**. The foil **2450** is wrapped around shielded detector with the foil side in and the aperture **2452** is aligned with the EMI shield grid **2444**.

Detector Assembly

FIG. **25** illustrates an alternative detector assembly **2400** embodiment having adjacent detectors. Optical radiation having multiple wavelengths generated by emitters **700** is transmitted into a tissue site **1**. Optical radiation at a first set of wavelengths is detected by a first detector **2510**, such as, for example, a Si detector. Optical radiation at a second set of wavelengths is detected by a second detector **2520**, such as, for example, a GaAs detector.

FIG. **26** illustrates another alternative detector assembly **2400** embodiment having stacked detectors coaxial along a light path. Optical radiation having multiple wavelengths generated by emitters **700** is transmitted into a tissue site **1**. Optical radiation at a first set of wavelengths is detected by a first detector **2610**. Optical radiation at a second set of wavelengths passes through the first detector **2610** and is detected by a second detector **2620**. In a particular embodiment, a silicon (Si) detector and a gallium arsenide (GaAs) detector are used. The Si detector is placed on top of the GaAs detector so that light must pass through the Si detector before reaching the GaAs detector. The Si detector can be placed directly on top of the GaAs detector or the Si and GaAs detector can be separated by some other medium, such as a transparent medium or air. In another particular embodiment, a germanium detector is used instead of the GaAs detector. Advantageously, the stacked detector arrangement minimizes error caused by pathlength differences as compared with the adjacent detector embodiment.

Finger Clip

FIG. **27** illustrates a finger clip embodiment **2700** of a physiological sensor attachment assembly. The finger clip **2700** is configured to removably attach an emitter assembly **500** (FIG. **6**) and detector assembly **2400** (FIG. **24**), interconnected by a flex circuit assembly **1900**, to a fingertip. The finger clip **2700** has an emitter shell **3800**, an emitter pad **3000**, a detector pad **2800** and a detector shell **3900**. The emitter shell **3800** and the detector shell **3900** are rotatably connected and urged together by the spring assembly **3500**. The emitter pad **3000** is fixedly retained by the emitter shell. The emitter assembly **500** (FIG. **6**) is mounted proximate the emitter pad **3000** and adapted to transmit optical radiation having a plurality of wavelengths into fingertip tissue. The detector pad **2800** is fixedly retained by the detector shell **3900**. The detector assembly **3500** is mounted proximate the detector pad **2800** and adapted to receive the optical radiation after attenuation by fingertip tissue.

FIG. **28** illustrates a detector pad **2800** advantageously configured to position and comfortably maintain a fingertip relative to a detector assembly for accurate sensor measurements. In particular, the detector pad has fingertip positioning features including a guide **2810**, a contour **2820** and a stop **2830**. The guide **2810** is raised from the pad surface **2803** and narrows as the guide **2810** extends from a first end **2801** to a second end **2802** so as to increasingly conform to a fingertip as a fingertip is inserted along the pad surface **2803** from the first end **2801**. The contour **2820** has an indentation defined along the pad surface **2803** generally shaped to conform to a fingertip positioned over a detector aperture **2840** located within the contour **2820**. The stop **2830** is raised from the pad surface **2803** so as to block the end of a finger from inserting beyond the second end **2802**. FIGS. **29**A-B illustrate detector pad embodiments **3100**, **3400** each having a guide **2810**, a contour **2820** and a stop **2830**, described in further detail with respect to FIGS. **31** and **34**, respectively.

FIGS. **30**A-H illustrate an emitter pad **3000** having emitter pad flaps **3010**, an emitter window **3020**, mounting pins **3030**, an emitter assembly cavity **3040**, isolation notches **3050**, a flex circuit notch **3070** and a cable notch **3080**. The emitter pad flaps **3010** overlap with detector pad flaps **3110** (FIGS. **31**A-H) to block ambient light. The emitter window **3020** provides an optical path from the emitter array **700** (FIG. **8**) to a tissue site. The mounting pins **3030** accommodate apertures in the flex circuit mounting ears **2214** (FIG. **22**), and the cavity **3040** accommodates the emitter assembly **500** (FIG. **21**). Isolation notches **3050** mechanically decouple the shell attachment **3060** from the remainder of the emitter pad **3000**. The flex circuit notch **3070** accommodates the flex circuit tail **2206** (FIG. **22**) routed to the detector pad **3100** (FIGS. **31**A-H). The cable notch **3080** accommodates the sensor cable **4400** (FIGS. **44**A-B). FIGS. **33**A-H illustrate an alternative slim finger emitter pad **3300** embodiment.

FIGS. **31**A-H illustrate a detector pad **3100** having detector pad flaps **3110**, a shoe box cavity **3120** and isolation notches **3150**. The detector pad flaps **3110** overlap with emitter pad flaps **3010** (FIGS. **30**A-H), interleaving to block ambient light. The shoe box cavity **3120** accommodates a shoe box **3200** (FIG. **32**A-H) described below. Isolation notches **3150** mechanically decouple the attachment points **3160** from the remainder of the detector pad **3100**. FIGS. **34**A-H illustrate an alternative slim finger detector pad **3400** embodiment.

FIGS. **32**A-H illustrate a shoe box **3200** that accommodates the detector assembly **2400** (FIG. **24**). A detector window **3210** provides an optical path from a tissue site to the detector **2410** (FIG. **24**). A flex circuit notch **3220** accommodates the flex circuit tail **2206** (FIG. **22**) routed from the emitter pad **3000** (FIGS. **30**A-H). In one embodiment, the shoe box **3200** is colored black or other substantially light absorbing color and the emitter pad **3000** and detector pad **3100** are each colored white or other substantially light reflecting color.

FIGS. **35**-**37** illustrate a spring assembly **3500** having a spring **3600** configured to urge together an emitter shell **3800** (FIG. **46**) and a detector shell **3900**. The detector shell is rotatably connected to the emitter shell. The spring is disposed between the shells **3800**, **3900** and adapted to create a pivot point along a finger gripped between the shells that is substantially behind the fingertip. This advantageously

allows the shell hinge **3810**, **3910** (FIGS. **38-39**) to expand so as to distribute finger clip force along the inserted finger, comfortably keeping the fingertip in position over the detector without excessive force.

As shown in FIGS. **36**A-C, the spring **3600** has coils **3610**, an emitter shell leg **3620** and a detector shell leg **3630**. The emitter shell leg **3620** presses against the emitter shell **3800** (FIGS. **38**A-D) proximate a grip **3820** (FIGS. **38**A-D). The detector shell legs **3630** extend along the detector shell **3900** (FIGS. **39**A-D) to a spring plate **3700** (FIGS. **37**A-D) attachment point. The coil **3610** is secured by hinge pins **410** (FIG. **46**) and is configured to wind as the finger clip is opened, reducing its diameter and stress accordingly.

As shown in FIGS. **37**A-D the spring plate **3700** has attachment apertures **3710**, spring leg slots **3720**, and a shelf **3730**. The attachment apertures **3710** accept corresponding shell posts **3930** (FIGS. **39**A-D) so as to secure the spring plate **3700** to the detector shell **3900** (FIG. **39**A-D). Spring legs **3630** (FIG. **36**A-C) are slidably anchored to the detector shell **3900** (FIG. **39**A-D) by the shelf **3730**, advantageously allowing the combination of spring **3600**, shells **3800**, **3900** and hinges **3810**, **3910** to adjust to various finger sizes and shapes.

FIGS. **38-39** illustrate the emitter and detector shells **3800**, **3900**, respectively, having hinges **3810**, **3910** and grips **3820**, **3920**. Hinge apertures **3812**, **3912** accept hinge pins **410** (FIG. **46**) so as to create a finger clip. The detector shell hinge aperture **3912** is elongated, allowing the hinge to expand to accommodate a finger.

Monitor and Sensor

FIG. **40** illustrates a monitor **100** and a corresponding sensor assembly **200**, as described generally with respect to FIGS. **1-3**, above. The sensor assembly **200** has a sensor **400** and a sensor cable **4400**. The sensor **400** houses an emitter assembly **500** having emitters responsive to drivers within a sensor controller **4500** so as to transmit optical radiation into a tissue site. The sensor **400** also houses a detector assembly **2400** that provides a sensor signal **2500** responsive to the optical radiation after tissue attenuation. The sensor signal **2500** is filtered, amplified, sampled and digitized by the front-end **4030** and input to a DSP (digital signal processor) **4040**, which also commands the sensor controller **4500**. The sensor cable **4400** electrically communicates drive signals from the sensor controller **4500** to the emitter assembly **500** and a sensor signal **2500** from the detector assembly **2400** to the front-end **4030**. The sensor cable **4400** has a monitor connector **210** that plugs into a monitor sensor port **110**.

In one embodiment, the monitor **100** also has a reader **4020** capable of obtaining information from an information element (IE) in the sensor assembly **200** and transferring that information to the DSP **4040**, to another processor or component within the monitor **100**, or to an external component or device that is at least temporarily in communication with the monitor **100**. In an alternative embodiment, the reader function is incorporated within the DSP **4040**, utilizing one or more of DSP I/O, ADC, DAC features and corresponding processing routines, as examples.

In one embodiment, the monitor connector **210** houses the information element **4000**, which may be a memory device or other active or passive electrical component. In a particular embodiment, the information element **4000** is an EPROM, or other programmable memory, or an EEPROM, or other reprogrammable memory, or both. In an alternative embodiment, the information element **4000** is housed within the sensor **400**, or an information element **4000** is housed within both the monitor connector **4000** and the sensor **400**. In yet another embodiment, the emitter assembly **500** has an information element **4000**, which is read in response to one or more drive signals from the sensor controller **4500**, as described with respect to FIGS. **41-43**, below. In a further embodiment, a memory information element is incorporated into the emitter array **700** (FIG. **8**) and has characterization information relating to the LEDs **801** (FIG. **8**). In one advantageous embodiment, trend data relating to slowly varying parameters, such as perfusion index, HbCO or METHb, to name a few, are stored in an IE memory device, such as EEPROM.

Back-to-Back LEDs

FIGS. **41-43** illustrate alternative sensor embodiments. A sensor controller **4500** configured to activate an emitter array **700** (FIG. **7**) arranged in an electrical grid, is described with respect to FIG. **7**, above. Advantageously, a sensor controller **4500** so configured is also capable of driving a conventional two-wavelength (red and IR) sensor **4100** having back-to-back LEDs **4110**, **4120** or an information element **4300** or both.

FIG. **41**A illustrates a sensor **4100** having an electrical grid **4130** configured to activate light emitting sources by addressing at least one row conductor and at least one column conductor. A first LED **4110** and a second LED **4120** are configured in a back-to-back arrangement so that a first contact **4152** is connected to a first LED **4110** cathode and a second LED **4120** anode and a second contact **4154** is connected to a first LED **4110** anode and a second LED **4120** cathode. The first contact **4152** is in communications with a first row conductor **4132** and a first column conductor **4134**. The second contact is in communications with a second row conductor **4136** and a second column conductor **4138**. The first LED **4110** is activated by addressing the first row conductor **4132** and the second column conductor **4138**. The second LED **4120** is activated by addressing the second row conductor **4136** and the first column conductor **4134**.

FIG. **41**B illustrates a sensor cable **4400** embodiment capable of communicating signals between a monitor **100** and a sensor **4100**. The cable **4400** has a first row input **4132**, a first column input **4134**, a second row input **4136** and a second column input **4138**. A first output **4152** combines the first row input **4132** and the first column input **4134**. A second output **4154** combines a second row input **4136** and second column input **4138**.

FIG. **41**C illustrates a monitor **100** capable of communicating drive signals to a sensor **4100**. The monitor **4400** has a first row signal **4132**, a first column signal **4134**, a second row signal **4136** and a second column signal **4138**. A first output signal **4152** combines the first row signal **4132** and the first column signal **4134**. A second output signal **4154** combines a second row signal **4136** and second column signal **4138**.

Information Elements

FIGS. **42-43** illustrate information element **4200-4300** embodiments in communications with emitter array drivers configured to activate light emitters connected in an electrical grid. The information elements are configured to provide information as DC values, AC values or a combination of DC and AC values in response corresponding DC, AC or combination DC and AC electrical grid drive signals. FIG. **42** illustrates information element embodiment **4200** advantageously driven directly by an electrical grid having rows **710** and columns **720**. In particular, the information element **4200** has a series connected resistor R_2 **4210** and diode **4220** connected between a row line **710** and a column line **720** of an electrical grid. In this manner, the resistor R_2 value can be read in a similar manner that LEDs **810** (FIG. **8**) are activated. The diode **4220** is oriented, e.g. anode to row and cathode to

column as the LEDs so as to prevent parasitic currents from unwanted activation of LEDs **810** (FIG. **8**).

FIGS. **43**A-C illustrate other embodiments where the value of R_1 is read with a DC grid drive current and a corresponding grid output voltage level. In other particular embodiments, the combined values of R_1, R_2 and C or, alternatively, R_1, R_2 and L are read with a varying (AC) grid drive currents and a corresponding grid output voltage waveform. As one example, a step in grid drive current is used to determine component values from the time constant of a corresponding rise in grid voltage. As another example, a sinusoidal grid drive current is used to determine component values from the magnitude or phase or both of a corresponding sinusoidal grid voltage. The component values determined by DC or AC electrical grid drive currents can represent sensor types, authorized suppliers or manufacturers, emitter wavelengths among others. Further, a diode D (FIG. **43**C) can be used to provide one information element reading R_1 at one drive level or polarity and another information element reading, combining R_1 and R_2, at a second drive level or polarity, i.e. when the diode is forward biased.

Passive information element **4300** embodiments may include any of various combinations of resistors, capacitors or inductors connected in series and parallel, for example. Other information element **4300** embodiments connected to an electrical grid and read utilizing emitter array drivers incorporate other passive components, active components or memory components, alone or in combination, including transistor networks, PROMs, ROMs, EPROMs, EEPROMs, gate arrays and PLAs to name a few.

Sensor Cable

FIGS. **44**A-B illustrate a sensor cable **4400** having an outer jacket **4410**, an outer shield **4420**, multiple outer wires **4430**, an inner jacket **4440**, an inner shield **4450**, a conductive polymer **4460** and an inner twisted wire pair **4470**. The outer wires **4430** are advantageously configured to compactly carry multiple drive signals to the emitter array **700** (FIG. **7**). In one embodiment, there are twelve outer wires **4430** corresponding to four anode drive signals **4501** (FIG. **45**), four cathode drive signals **4502** (FIG. **45**), two thermistor pinouts **1450** (FIG. **15**) and two spares. The inner twisted wire pair **4470** corresponds to the sensor signal **2500** (FIG. **25**) and is extruded within the conductive polymer **4460** so as to reduce triboelectric noise. The shields **4420**, **4450** and the twisted pair **4470** boost EMI and crosstalk immunity for the sensor signal **2500** (FIG. **25**).

Controller

FIG. **45** illustrates a sensor controller **4500** located in the monitor **100** (FIG. **1**) and configured to provide anode drive signals **4501** and cathode drive signals **4502** to the emitter array **700** (FIG. **7**). The DSP (digital signal processor) **4040**, which performs signal processing functions for the monitor, also provides commands **4042** to the sensor controller **4500**. These commands determine drive signal **4501**, **4502** levels and timing. The sensor controller **4500** has a command register **4510**, an anode selector **4520**, anode drivers **4530**, current DACs (digital-to-analog converters) **4540**, a current multiplexer **4550**, cathode drivers **4560**, a current meter **4570** and a current limiter **4580**. The command register **4510** provides control signals responsive to the DSP commands **4042**. In one embodiment, the command register **4510** is a shift register that loads serial command data **4042** from the DSP **4040** and synchronously sets output bits that select or enable various functions within the sensor controller **4500**, as described below.

As shown in FIG. **45**, the anode selector **4520** is responsive to anode select **4516** inputs from the command register **4510** that determine which emitter array row **810** (FIG. **8**) is active. Accordingly, the anode selector **4520** sets one of the anode on **4522** outputs to the anode drivers **4530**, which pulls up to Vcc one of the anode outputs **4501** to the emitter array **700** (FIG. **8**).

Also shown in FIG. **45**, the current DACs **4540** are responsive to command register data **4519** that determines the currents through each emitter array column **820** (FIG. **8**). In one embodiment, there are four, 12-bit DACs associated with each emitter array column **820** (FIG. **8**), sixteen DACs in total. That is, there are four DAC outputs **4542** associated with each emitter array column **820** (FIG. **8**) corresponding to the currents associated with each row **810** (FIG. **8**) along that column **820** (FIG. **8**). In a particular embodiment, all sixteen DACs **4540** are organized as a single shift register, and the command register **4510** serially clocks DAC data **4519** into the DACs **4540**. A current multiplexer **4550** is responsive to cathode on **4518** inputs from the command register **4510** and anode on **4522** inputs from the anode selector **4520** so as to convert the appropriate DAC outputs **4542** to current set **4552** inputs to the cathode drivers **4560**. The cathode drivers **4560** are responsive to the current set **4552** inputs to pull down to ground one to four of the cathode outputs **4502** to the emitter array **700** (FIG. **8**).

The current meter **4570** outputs a current measure **4572** that indicates the total LED current driving the emitter array **700** (FIG. **8**). The current limiter **4580** is responsive to the current measure **4572** and limits specified by the command register **4510** so as to prevent excessive power dissipation by the emitter array **700** (FIG. **8**). The current limiter **4580** provides an enable **4582** output to the anode selector **4520**. A Hi Limit **4512** input specifies the higher of two preset current limits. The current limiter **4580** latches the enable **4582** output in an off condition when the current limit is exceeded, disabling the anode selector **4520**. A trip reset **4514** input resets the enable **4582** output to re-enable the anode selector **4520**.

Sensor Assembly

As shown in FIG. **46**, the sensor **400** has an emitter shell **3800**, an emitter pad **3000**, a flex circuit assembly **2200**, a detector pad **3100** and a detector shell **3900**. A sensor cable **4400** attaches to the flex circuit assembly **2200**, which includes a flex circuit **2100**, an emitter assembly **500** and a detector assembly **2400**. The portion of the flex circuit assembly **2200** having the sensor cable **4400** attachment and emitter assembly **500** is housed by the emitter shell **3800** and emitter pad **3000**. The portion of the flex circuit assembly **2200** having the detector assembly **2400** is housed by the detector shell **3900** and detector pad **3100**. In particular, the detector assembly **2400** inserts into a shoe **3200**, and the shoe **3200** inserts into the detector pad **3100**. The emitter shell **3800** and detector shell **3900** are fastened by and rotate about hinge pins **410**, which insert through coils of a spring **3600**. The spring **3600** is held to the detector shell **3900** with a spring plate **3700**. A finger stop **450** attaches to the detector shell. In one embodiment, a silicon adhesive **420** is used to attach the pads **3000**, **3100** to the shells **3800**, **3900**, a silicon potting compound **430** is used to secure the emitter and detector assemblies **500**, **2400** within the pads **3000**, **3100**, and a cyanoacrylic adhesive **440** secures the sensor cable **4400** to the emitter shell **3800**.

A multiple wavelength sensor has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to

limit the scope of the claims that follow. One of ordinary skill in art will appreciate many variations and modifications.

What is claimed is:

1. A physiological sensor comprising:

a plurality of emitters configured to transmit optical radiation having a plurality of wavelengths in response to a corresponding plurality of drive currents, the plurality of emitters including a substrate;

a thermal mass disposed proximate the emitters and within the substrate so as to stabilize a bulk temperature for the emitters; and

a temperature sensor thermally coupled to the thermal mass,

wherein the temperature sensor provides a temperature sensor output responsive to the bulk temperature so that the wavelengths are determinable as a function of the drive currents and the bulk temperature.

2. The physiological sensor according to claim **1** wherein the substrate has a first side and a second side,

wherein the emitters are mounted to the first side, and

wherein the temperature sensor is mounted to the second side.

3. The physiological sensor according to claim **2** wherein the temperature sensor is a thermistor and the emitters are LEDs.

4. The physiological sensor according to claim **3**:

wherein the thermal mass is a plurality of layers of the substrate.

5. The physiological sensor of claim **4** wherein each of the layers of the thermal mass is substantially copper clad.

6. The physiological sensor according to claim **1**:

wherein the thermal mass is disposed within the substrate proximate the light emitting sources and the temperature sensor.

7. A physiological sensor capable of emitting light into tissue and producing an output signal usable to determine one or more physiological parameters of a patient, the physiological sensor comprising:

a thermal mass;

a plurality of light emitting sources, including a substrate of the plurality of light emitting sources, thermally coupled to the thermal mass, the sources having a corresponding plurality of operating wavelengths, the thermal mass disposed within the substrate;

a temperature sensor thermally coupled to the thermal mass and capable of determining a bulk temperature for the thermal mass, the operating wavelengths dependent on the bulk temperature; and

a detector capable of detecting light emitted by the light emitting sources after tissue attenuation, wherein the detector is capable of outputting a signal usable to determine one or more physiological parameters of a patient based upon the operating wavelengths.

8. The physiological sensor according to claim **7**:

wherein the thermal mass is disposed within the substrate proximate the light emitting sources and the temperature sensor.

9. The physiological sensor according to claim **7** wherein the temperature sensor comprises a thermistor.

10. The physiological sensor according to claim **9** wherein the light emitting sources are disposed on a first side of the substrate and the temperature sensor is disposed on a second side of the substrate.

11. The physiological sensor according to claim **7** wherein the thermal mass is a plurality of layers of the substrate.

12. The physiological sensor of claim **11** wherein each of the layers of the thermal mass is substantially copper clad.

13. In a physiological sensor adapted to determine a physiological parameter using a plurality of light emitting sources with emission wavelengths affected by one or more dynamic operating parameters, a sensor method comprising:

providing a thermal mass disposed within the substrate proximate the light emitting sources and a temperature sensor thermally coupled to the thermal mass;

transmitting optical radiation from the plurality of light emitting sources into body tissue;

detecting the optical radiation after tissue attenuation; and

determining a plurality of operating wavelengths of the light emitting sources dependent on a bulk temperature of the light emitting sources so that one or more physiological parameters of a patient can be determined based upon the operating wavelengths.

14. The physiological sensor method according to claim **13** wherein the determining step comprises stabilizing the bulk temperature for the light emitting sources.

15. The physiological sensor method according to claim **14** wherein the determining further comprises thermally coupling a thermistor to the light emitting sources so as to indicate the bulk temperature.

16. The physiological sensor method according to claim **15** further comprising disposing the thermistor proximate the light emitting sources.

17. The physiological sensor according to claim **13** wherein the thermal mass is disposed within the substrate proximate the light emitting sources and the temperature sensor.

18. The physiological sensor method according to claim **13** wherein the thermal mass is a plurality of layers of the substrate.

19. The physiological sensor method according to claim **18** wherein each of the layers of the thermal mass is substantially copper clad.

20. In a physiological sensor adapted to determine a physiological parameter using a plurality of light emitting sources with emission wavelengths affected by one or more dynamic operating parameters, a sensor method comprising:

providing a thermal mass disposed within a substrate of the light emitting sources and a temperature sensor thermally coupled to the thermal mass;

transmitting optical radiation from the plurality of light emitting sources into body tissue;

detecting the optical radiation after tissue attenuation; and

indicating an operating wavelength for each of the plurality of light emitting sources.

21. The physiological sensor method according to claim **20** wherein the indicating step comprises measuring a bulk temperature for the light emitting sources.

22. The physiological sensor method according to claim **21** wherein the indicating further comprises utilizing a thermistor thermally coupled to the light emitting sources so as to measure a bulk temperature.

23. The physiological sensor according to claim **20** wherein the thermal mass is disposed within the substrate proximate the light emitting sources and the temperature sensor.

24. The physiological sensor method according to claim **20** wherein the thermal mass is a plurality of layers of the substrate.

25. The physiological sensor method according to claim **24** wherein each of the layers of the thermal mass is substantially copper clad.

26. A physiological sensor comprising:

a plurality of emitters configured to transmit optical radiation having a plurality of wavelengths in response to a corresponding plurality of drive currents;

a thermal mass disposed proximate the emitters and within a substrate so as to stabilize a bulk temperature for the emitters; and

a temperature sensor thermally coupled to the thermal mass,

wherein the temperature sensor provides a temperature sensor output responsive to the bulk temperature so that the wavelengths are determinable as a function of the drive currents and the bulk temperature;

a substrate having a top side and a bottom side,

wherein the emitters are mounted to the top side, and

wherein the temperature sensor is mounted to the bottom side.

27. The physiological sensor according to claim **26** wherein the temperature sensor is a thermistor and the emitters are LEDs.

28. The physiological sensor according to claim **26** wherein the thermal mass is a plurality of layers of the substrate.

29. The physiological sensor of claim **28** wherein each of the layers of the thermal mass is substantially copper clad.

30. The physiological sensor according to claim **26**:

wherein the light emitting sources and the temperature sensor are disposed on the substrate, and

wherein the thermal mass is disposed within the substrate proximate the light emitting sources and the temperature sensor.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,761,127 B2
APPLICATION NO. : 11/366209
DATED : July 20, 2010
INVENTOR(S) : Ammar Al-Ali et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Page 2, Line 9, Column 2, change "$I_\lambda = I_{0,\lambda} e^{-d_\lambda \cdot \mu_{a,\lambda}}$" to -- $I_\lambda = I_{0,\lambda} e^{-d_\lambda \cdot \mu_{a,\lambda}}$ --.

Claim 13, change "the substrate" to -- a substrate --.

Signed and Sealed this
Fourth Day of January, 2011

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office

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Claim 13, Column 20, Line 5, change "the substrate" to -- a substrate --.

This certificate supersedes the Certificate of Correction issued January 4, 2011.

Signed and Sealed this
First Day of February, 2011

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office